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May 15, 2025

To: Postodoctoral Candidate Selection Committee

Subject: RE: Recommendation Letter for Bassel El Mabsout

Dear Sir or Madam,

I am writing to provide the strongest and most enthusiastic support for Bassel El Mabsout, as I am aware that he is under consideration for a Postodoctoral Researcher position at your institution. **Bassel is a superstar with incredible research potential and truly exceptional intellectual abilities**. I am very confident that Bassel will thrive at your institution, will be an absolute asset in the department, and will be an amazing, reliable colleague to have around for collaborative work. In the remainder of this letter, I will briefly introduce myself and then explain why Bassel is an incredible candidate to consider for the position.

My name is Renato Mancuso, and I am an Associate Professor in the Computer Science Department at Boston University (BU). I earned my Ph.D. in Computer Science from the University of Illinois at Urbana-Champaign (UIUC) in 2017. Over the last twelve years, I have dedicated my research to the development of innovative OS- and hardware-level strategies to address the emerging challenges in cyber-physical systems. I particularly focused on providing hard real-time guarantees in high-performance safety-critical systems. My academic contributions have resulted in over 80 refereed publications and have garnered more than 2800 citations, according to Google Scholar[1]. My research has received support from the National Science Foundation (NSF) and multiple industrial partners, including Bosch, Red Hat Research, Cisco, and AMD/Xilinx. I was the recipient of the prestigious ACM/SIGBED Early Career Researcher Award in 2024. I received the NSF CAREER Award in 2023 and the BU Gitner Family Teaching Award the same year. I was also the recipient of a number of service and research awards at top conferences in my field. With this background, I am in a position to aptly assess Bassel's capabilities and potential. I have also been part of multiple Ph.D. and faculty search committees at BU, and I can explain why Bassel would be a candidate that I would be excited to consider if he was applying for a similar position at BU.

In short, Bassel's role in my Cyber-Physical Systems lab has been simultaneously that of a Ph.D. candidate, an advisor, and a collaboration enabler. I owe Bassel the incredible recognition that my group has received in the AI/ML community despite Bassel being the *only* reason why my group is relatively well recognized in that field to start with. Indeed, one thing that needs to be absolutely clear when considering Bassel is that my main expertise (and that of pretty much all of my other students) is quite

[1] `https://scholar.google.com/citations?user=gDkEWtYAAAAJ`

far from Bassel's line of research. Upon joining my group, **Bassel single-handedly defined his own research line, focusing on a concrete problem that genuinely excites him: enabling efficient and *surprise-free* reinforcement learning-based (RL) training of real robot controllers.**

Throughout his academic path as a Ph.D. student, Bassel has always been the one coming up with the problems he wanted to solve and with principled solutions to approach them. What is even more impressive is that Bassel did not have a background in RL or ML when he first joined my group, and neither did I. Allow me to explain Bassel's academic path.

Bassel applied to the Ph.D. program at BU back in 2019 with a strong background in programming languages and formal methods. As a matter of fact, Bassel was hired as a *floater* in the program. At BU, we hire a very small percentage of students from the applicant pool who do not come with a pre-secured advisor, but that are **too strong** to pass on. Bassel was identified as a student with incredible potential by one of our most senior faculty members, a world-class expert on programming languages, my colleague Prof. Assaf Kfoury. Prof. Kfoury is approaching emeritus status and thus not as research-active anymore. Nonetheless, he foresaw Bassel's potential the moment he came across his Ph.D. application back in 2019. As such, Bassel was formally Prof. Kfoury's advisee at the beginning of his Ph.D. while he looked for a more permanent, research-active advisor.

Bassel approached me not long after he arrived at BU, and I was immediately struck by his incredible intellectual maturity and insightfulness. At the time, my lab was far from being established and I outlined my vision of building a lab with strong hands-on expertise in real-world robotics. At the time (and to date), my idea was that when approaching real problems in this class of cyber-physical systems, theoretical solutions are an excellent starting point but not the final goal. This field is still in dire need of technological breakthroughs, which are only possible when theoretically-principled solutions are refined by considering the nuances of realistic implementations and ultimately deployed/tested on actual systems. My lab strongly follows this philosophy when working on OS/hardware-level techniques to guarantee timeliness. What amazed me was how well **Bassel resonated with this philosophy at a fundamental level while immediately manifesting his interest in applying the same mindset to the problem of RL-based robot control.** In light of this and given his strong theoretical background, I knew right away that he would be pivotal in my research group. Since then, Bassel has been a defining force in my lab.

Impact and Growth in my Research Group. Since 2019, Bassel has co-authored four publications, with three more works under active submission and already on ArXiv and at least three more in the pipeline at the time of writing this letter. I am aware that in terms of pure bin counting, the sheer number of publications might not compare well to other candidates from the AI/ML area that you might be considering. However, I want you to consider three key factors.

First, as I mentioned above, research in AI/ML was not in my wheelhouse before Bassel joined my group. **He has identified, learned, and taught me much of the relevant literature throughout his time at BU!** Second, many Ph.D. candidates in this area publish works at a very sustained rate by simply re-implementing existing techniques and tweaking the parameters of existing toolboxes to fit niche problems. Conversely, **Bassel always approached fundamental problems, questioned the theoretical foundation of RL methods, and has set his focus on structural changes that can improve their usefulness when applied to real systems.** Bassel has never focused on *low-hanging fruits* and each of his papers represents a sizable milestone toward closing what he defines as the *intent-to-behavior gap* in RL-based robot control problems. Third, his work has already received huge visibility. His co-first-author paper titled "Regularizing Action Policies for Smooth Control with Reinforcement Learning" (ICRA, 2021) is the work that has been rising in number of citations the fastest in my profile. Indeed, it is my most recent highly cited work—all the other works with a higher citation index are from 2013–2019). One of his other co-first authored papers titled "How to train your quadrotor: A framework for consistently smooth and responsive flight control via reinforcement learning" (ACM Trans. on Cyber-Physical Sys., 2021) is the third most-cited work from 2021 or earlier in my lab. Overall, Bassel is by far the student in my group with the fastest-growing impact record.

Indeed, let me put that into a perspective that can shine even more light on Bassel's potential. My lab just graduated what I consider to be a very successful Ph.D. student, namely Shahin Roozkhosh. Shahin has been very productive, with 14 peer-reviewed publications (see `https://scholar.google.com/citations?user=pStR1w4AAAAJ&hl=en`) in his record at the time of graduation. Shahin has had the advantage of working in exactly my area of expertise, solving many of the problems that I identified, with solutions that I substantially helped him devise and shape. Moreover, Shahin started publishing in 2016, before he even joined BU. Bassel, on the other hand, was largely self-advised, identified by himself the problems he wanted to focus on, bootstrapped his own collaborations, and started publishing a full 4 years later than Shahin. Yet, Bassel (see `https://scholar.google.com/citations?hl=en&user=Rxv9W98AAAAJ`) has only three fewer citations than Shahin since 2020. Bassel has already surpassed Shahin's citation count in 2024; in 2025 he has 3× more citations than Shahin. Thus, if I were to wear my hat as a postdoctoral researcher admissions committee member, I would certainly consider Shahin as a *safe bet* in terms of readiness for a postdoctoral researcher position. **However, when considering his trajectory, I would be even more excited at the prospect of hiring Bassel!**

Collaboration Record. In addition to his externally visible scholarly contributions, Bassel has been an incredible asset in my research lab when it comes to establishing and maintaining collaborations. As I mentioned above, he independently established his network of collaborators, which greatly helped him shape his work.

In particular, he was able to engage with Prof. Kate Saenko (BU, CS) who is considered a top-ranking

AI/ML researcher. Prof. Saenko runs a very large group and seldom works with researchers in the systems group like myself. Bassel was the perfect connector that enabled all of our collaborative work. The work that Bassel co-authored with Sid Mysore—a recently graduated Prof. Saenko's advisee—is testament to how successful has been said collaboration.

Bassel was also functional for me to bootstrap a new promising joint line of work with Prof. Sabrina Neuman (BU, CS). Prof. Neuman works on computer architectures tailored to multi-limb robots. The work that Bassel has pioneered was interesting for her because it unlocked the possibility of bringing advanced control techniques to small-scale quadruped robots. To gather preliminary results on the viability of the project, Bassel set up an RL-based controller that could be deployed on the small-factor Bittle Robot Dog. In the process, he also trained a student from Prof. Neuman's group on RL with inverse kinematics. This project is still in flux, but the current plan is to submit a joint proposal for consideration to the NSF in the next few months.

In the same way, he has reached out to Prof. Bingzhuo Zhong (Hong Kong University of Science and Technology) on techniques to formally verify the correctness of RL-based controllers. I encourage anyone reading this letter to ask him about this line of work during the one-on-one interviews. Because of this connection, Bassel was invited and offered funding for a visiting scholar period at the Technical University of Munich (TUM) where Prof. Zhong was a postdoctoral researcher at the time. Unfortunately, Bassel was unable to exit the USA because re-entry would have been problematic due to his Lebanese citizenship. He has since then applied for permanent resident status in the USA. I also expect that Bassel will resume the work with Prof. Zhong in the future.

More recently, he spontaneously connected with Abdelrahman Abdelgawad when he was a B.Sc. student at the Egypt-Japan University of Science and Technology in New Borg El Arab, Egypt. The two of them connected without my involvement over email and started collaborating together on what I believe is Bassel's **most impactful research contribution by far**, namely *Fulfillment Priority Logic* (FPL)—I will discuss why FPL is such a game-changer for RL-based control below. Interestingly enough, Abdelrahman received a number of Ph.D. admissions. He decided to start his Ph.D. at BU specifically because of his connection with Bassel. They have now established a long-term vision for collaborative work that I am sure will define the early stages of Bassel's tenure. Once again, this is work that he has already independently established, with my role so far having been pretty much that of a *devil's advocate* when he presents his ideas and forms his publications.

Furthermore, back in the summer of 2021, I decided to get involved in the RISE program at BU. The mission of the RISE program is to involve very promising high-school seniors in research in the last year before they apply for college. At that time, I decided to advise Abhinav Pomalapally. Given my very limited bandwidth, I asked Bassel to advise Abhinav. Bassel did an amazing job, and four years later, he is still in contact with Abhinav. The work that they started during that summer is now under

submission for publication! A recently updated version of their work titled "Scrap Your Schedules with PopDescent" is already on ArXiv as of April 2024. The positive impact that Bassel has had on Abhinav is quite tangible since Abhinav was admitted as a B.Sc. student at UC Berkeley in the EECS department soon after. If this is at all representative of how good of an advisor Bassel is going to be, then I would be quite ecstatic at the prospect of hiring him as a colleague.

Exposure to Proposal Writing. Bassel has also been an incredible asset in my group when it comes to funding. First, he was directly involved in putting together a number of proposals to the NSF that were, unfortunately, unsuccessful. I can count at least three such proposals that I submitted early on during my tenure track and did not receive funding, mostly because I was still getting my footing on how to write competitive proposals as I started right after my Ph.D. at BU. Nonetheless, Bassel was incredibly helpful at writing entire sections and revising sections I initially drafted. This has exposed him early on to the process of proposal writing, something that will serve him well in the next chapter of his academic journey.

Apart from his help with unsuccessful proposals, Bassel was also a determinant force for successful proposals! Bassel helped me substantially in revising the research vision proposed in my NSF CAREER grant titled "Timeliness as a Controllable Dimension via Knowledge-driven System Management" (CSR-2238476) that received funding in 2023. Next, he was the main reason why our proposal, titled "Minimal Mobile Systems via Cloud-based Adaptive Task Processing," received funding from Red Hat Research two years in a row, 2023–2024 and 2024–2025. Most recently, his first-hand work on the writing and demo implementation was a key factor in our ability to win the *Best Demonstration Award* for Challenge 6 " Zero Trust Platform (SoC), System and Communication Architecture to Support Generative AI, LLM, from Cloud to Edge Continuum" at TII's GENZERO Workshop in Abu Dhabi, UAE in late 2024. Having received this award also allows my group to access a USD 1M funding opportunity reserved for GENZERO awardees. Bassel worked tirelessly on our pre-proposal titled "Burning Fetch Execution: A Framework for Zero-Trust Multi-Party Confidential Computing," on the hands-on demo and poster that we presented in Abu Dhabi, and on the final proposal we just submitted for TII's consideration.

Research Contribution. Beyond how Bassel's work impacted my group, I have already partially touched on how his research has already received substantial attention in the ML/AI community. Bassel's own Google Scholar profile now counts about 140 citations, with his first paper alone having gathered more than 99 citations since 2021! In order to better put into perspective the depth of Bassel's research work, I will briefly describe two published works and one under submission that are an excellent representation of Bassel's value as a researcher.

(Major Contribution #1) Bassel's first paper as a Ph.D. student is "How to train your quadrotor: A framework for consistently smooth and responsive flight control via reinforcement learning," which was published by Bassel as a co-first author in the ACM Trans. of Cyber-Physical Systems journal

in 2021. Quadrotor flight control has traditionally relied on classical Proportional-Integral-Derivative (PID) controllers, which, while effective, suffer from inherent limitations. They require extensive manual tuning and struggle with adaptability, especially in dynamic and unpredictable environments. Prior attempts to leverage reinforcement learning (RL) for quadrotor control had faced significant obstacles. These include poor sim-to-real transfer and high-frequency control oscillations that led to excessive power consumption and hardware wear. This paper constituted a breakthrough by addressing these limitations. In particular, it introduced and studied for the first time *multiplicative reward composition*, a novel method that improves learning stability and ensures better sim-to-real transfer. This approach prevents the loss of critical behaviors during training, enabling the first RL-based controller to match and even surpass PID performance in attitude control.

Building atop of multiplicative reward composition, the paper proposed RE+AL (REinforcement-based transferable Agents through Learning), a hybrid training framework that accelerates learning while improving control precision. This leads to a 10× reduction in training time, cutting the process from 9 hours to under 50 minutes. Additionally, previous RL controllers suffered from erratic, high-frequency control signals that degraded motor efficiency; this work achieves a 96% (!) reduction in control signal roughness and reduces oscillation frequency from 330 Hz to 130 Hz, making control responses significantly smoother. As a result, power consumption is reduced by 80%, making RL-based flight controllers not only feasible but also competitive with traditional methods for real-world quadrotor applications.

By addressing fundamental issues in RL-based control, such as training efficiency, robustness, and energy-aware decision-making, this work sets a new benchmark in robotics and reinforcement learning. The structured learning process ensures low tracking errors (4.2 deg/s) while maintaining smooth and responsive control, which is a critical requirement for drones operating in real-world scenarios. More broadly, the ideas introduced in this paper extend beyond quadrotor control with the potential to influence many other robotic applications requiring adaptive, high-precision control. This paper was, therefore, a major step toward making RL-driven controllers practical for autonomous aerial systems.

(Major Contribution #2) The work I mentioned above and titled "Regularizing action policies for smooth control with reinforcement learning" was published by Bassel as a co-first author at the 2021 IEEE International Conference on Robotics and Automation (ICRA). This work proposed Conditioning for Action Policy Smoothness (CAPS) as a more systematic way to address the challenges that his RE+AL framework tackled at the reward composition level. Indeed, CAPS capitalized on the fundamental understanding that Bassel developed about the challenges in training smooth and efficient RL-based controllers. CAPS introduces a structured framework to directly enforce the smoothness of control outputs directly at the policy regularization level.

CAPS introduces two critical regularization techniques: *temporal smoothness*, which ensures that control actions evolve gradually over time, and *spatial smoothness*, which guarantees that similar states yield con-

sistent control responses. Unlike traditional approaches that attempt to smooth control signals through indirect reward shaping, CAPS integrates these constraints directly into the RL optimization process. As a result, CAPS substantially reduces high-frequency oscillations, leading to a 50% reduction in power consumption without compromising flight accuracy. By prioritizing smooth control outputs, CAPS also mitigates hardware wear, making RL-based controllers more viable for real-world applications

By conditioning learned policies to favor smooth transitions, CAPS ensures that RL-based quadrotor controllers are not only fast and precise (as demonstrated by RE+AL) but also stable and energy-efficient. This advancement directly addresses one of the most critical barriers to deploying reinforcement learning in robotics: the trade-off between responsiveness and smooth control. CAPS effectively bridges this gap, making reinforcement learning a more practical and scalable solution for real-time control systems, particularly in energy-constrained autonomous flight applications.

(Major Contribution #3) Last but not least, the work titled "Closing the intent-to-behavior gap via Fulfillment Priority Logic" that Bassel has submitted as a first author and that is currently under review at 2025 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2025) is Bassel's crown jewel and a powerful indicator of the strength of his work to come. In this paper, Bassel introduces Fulfillment Priority Logic (FPL) which is the first domain-specific formal language to non-ambiguously express desired objective composition logic for training RL-based controllers. Expressing an expected behavior specification in FPL is as easy as using logical/temporal operators (and, or, not, this-before-that). FPL then leverages the power mean operator to automatically generate an equivalent algebraic formula that numerically captures and enforces the intended behavior at policy optimization time.

To demonstrate the power of FPL, Bassel co-designed a new RL training algorithm called Balanced Policy Gradient (BPG) that is an evolution of DDPG capable of exploiting specifications expressed in FPL. Thus, the FPL+BPG framework truly represents a significant step forward in RL, particularly in addressing the *intent-to-behavior gap*, i.e, the fundamental challenge in aligning a practitioner's high-level objectives with how learning agents actually behave. In this framework, Bassel introduces and showcases the power of a novel way to compose objectives using Q-value scalarization rather than traditional reward shaping. This method allows for a structured approach where objectives are prioritized dynamically, ensuring that the learning process remains stable while preserving critical behaviors. This approach provides a mathematically sound method to determine the relative satisfaction (fulfillment) of different objectives, allowing for a principled trade-off rather than relying on heuristics.

Experimental results demonstrate that FPL achieves up to 600% improvement in sample efficiency compared to state-of-the-art methods like Soft Actor-Critic. Moreover, FPL-trained policies exhibit substantially lower variability, leading to more consistent and predictable agent behavior. This has profound implications for reinforcement learning in robotics and real-world control tasks, where stability is critical. By providing an intuitive yet powerful language for specifying reinforcement learning objectives, FPL

significantly improves both the speed of policy training and the reliability of the resulting controllers.

Despite the works mentioned above being the most noteworthy already-published contributions, Bassel is already working on studying the far-reaching implications that his techniques have on (1) Lyapunov-based verification of RL controllers, (2) efficient training of controllers for systems with very non-linear dynamics, (3) vision-based autonomous systems and (4) multi-agent systems.

Work Attitude and Organizational Skills. One of the qualities that I admire most about Bassel is his exceptional organizational skills and ability to manage multiple complex tasks simultaneously. Throughout his time in my lab, he has consistently demonstrated a remarkable capacity to handle a diverse range of responsibilities—whether it be conducting intricate research experiments, working on designs to test new ideas, managing project timelines, helping with proposal writing, and helping with reviews. Despite the demands of balancing these roles, Bassel always approaches his work with a calm and methodical demeanor.

What truly sets him apart, however, is his ability to prioritize effectively. Even when faced with competing deadlines or challenging research obstacles, Bassel has shown a keen understanding of how to focus on what matters most to ensure that high-impact tasks receive the attention they require. His proactive attitude and disciplined approach to task management have not only contributed to his own success but have also significantly benefited the broader lab environment by ensuring smooth progress across multiple projects.

Leadership and Mentorship. Beyond his technical contributions, Bassel has been an indispensable leader within my lab. He took on the role of mentoring junior Ph.D. students and collaborators alike. He has been a reference point for several Master's and undergraduate students. Bassel has been involved in countless projects in the lab because he has a genuinely curious personality paired with the unique ability to swiftly pick up new complex concepts and ideas.

Perhaps most notable is the crucial role that Bassel played in mentoring students in a series of directed study courses with the goal of assembling and programming a competition-grade F1-tenth car for autonomous racing. His commitment to hands-on mentorship was unmatched: he spent countless late nights in the lab working alongside students, troubleshooting hardware and software issues, fine-tuning control algorithms, and ensuring the car was race-ready. His guidance was instrumental in helping the team become competitive, ultimately delivering a strong performance in competition against teams from prestigious institutions last November. Through his leadership, students not only developed technical expertise in robotics, real-time systems, and autonomous navigation but also gained invaluable experience in collaboration and problem-solving under real-world constraints. The team of students was so successful that they were able to secure intramural funding at BU to become a formally recognized student club, namely the "BU F1-Tenth Autonomous Racing Club".

Beyond the success of the racing club itself, Bassel's mentorship had a lasting impact on the students he worked with. Under his guidance, several of them have now launched a startup called Neobotics, aiming to commercialize ready-to-teach academic course packages on F1-Tenth autonomous racing. This venture is a testament to the depth of knowledge and inspiration that Bassel instilled in the team, demonstrating how his support extended beyond the race track and into entrepreneurial innovation. His ability to mentor students in both research and real-world applications has made a significant and enduring contribution to our community at BU.

Teaching Excellence. Bassel's teaching contributions extend beyond mentorship, as he played a crucial role as a Teaching Fellow (TF) for CS454/654 Embedded Systems Development when I taught it in Spring 2023. CS454/654 is a hands-on lab course that challenges students to apply real-time programming, firmware development, and control strategies to practical cyber-physical systems. His impact was particularly evident in the year he served as the TF, which turned out to be the most successful in terms of end-of-semester student projects. Bassel took on the ambitious task of designing a large-scale project and breaking it down into cohesive, interdependent sub-projects. This approach enabled student teams to work independently on meaningful components while ensuring that, when integrated, their collective efforts resulted in a final system that was more valuable than the sum of its parts. His ability to structure complex projects in an engaging and educational way significantly enhanced the students' learning experience and the overall course success.

Bassel's expertise in control theory has made him a recognized authority on the subject within the research lab. As a result, Shahin Roozkhosh, the aforementioned former Ph.D. student who now teaches CS454/654, has invited Bassel as a guest lecturer to cover the unit on control theory and practical control in this year's run of the class. His continued involvement in the course not only reflects his deep knowledge of embedded systems and control but also highlights his ongoing commitment to education and student mentorship, ensuring that future cohorts benefit from his expertise.

Future Vision. Building on his foundational work in RL for robotics, Bassel's future research aims to bridge the gap between learning efficiency and real-world deployability, particularly in the context of small, low-cost robotic systems. **His research vision is centered on making advanced learning-based control accessible to inexpensive, easily maintainable robots, which have the potential to attract and engage a wide range of students and researchers.** Many of these low-cost platforms—such as small quadrotors and entry-level ground robots—are severely constrained in terms of sensing capabilities, computational resources, and actuation precision. Traditional control methods often struggle to handle these limitations effectively, making them a prime candidate for RL-based strategies that can adaptively optimize performance despite hardware constraints. By refining RL techniques to support real-time adaptation, online learning, and multi-agent cooperation, Bassel seeks to enable these small, under-actuated robots to perform complex tasks with greater agility, efficiency, and robustness.

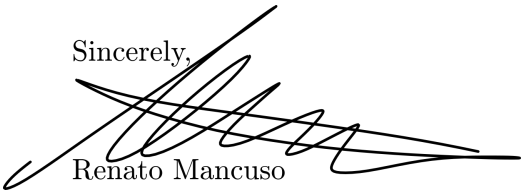
Another key goal in his future research is to integrate RL with formal safety guarantees, ensuring that these small-scale robots can operate reliably even with limited sensing and actuation. While RL has shown impressive performance in controlled environments, safety remains a significant challenge when deploying these systems in dynamic, real-world settings. **Bassel's work will focus on developing efficient learning algorithms that can operate under uncertainty while adhering to strict safety constraints**, an especially critical factor for robots that lack redundant sensors or high-fidelity state estimation. Additionally, he aims to advance sim-to-real transfer techniques, allowing these inexpensive robots to learn effectively in simulation before being deployed in physical environments, thus minimizing the cost and effort required for real-world experimentation. By making low-cost robotics a viable platform for high-performance, learning-based control, Bassel's research will democratize access to cutting-edge control strategies, empowering students, researchers, and enthusiasts alike to explore and innovate in robotics with minimal financial, real estate, and technical barriers.

Overall. Based on Bassel's remarkable academic impact, eclectic personality, strong technical skills, and spontaneous inclination toward research, I reaffirm my opening statement. Bassel truly is a superstar in the making who stands in a league of his own; he will be an incredible asset and dependable colleague to add to the ranks of your excellent research group and department. Any research agenda with a strong interdisciplinary nature will resonate incredibly well with his kaleidoscopic research interests ranging from programming languages to control theory, to RL, to formal methods, to robotics, and to real-time/embedded systems. He will (continue to) be an inspiring researcher, an amazing advisor, a passionate teacher, and an inclusive role model for students with a broad spectrum of backgrounds and interests.

Please feel free to reach out to me if you require any further information or have any questions. If the length of this letter is of any indication, I am always more than happy to further expand on why Bassel should be your first choice.

(NOTE: This letter was written without the use of generative AI.)

Sincerely,



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