Why should you be a part of Frontier Development Labs? Share with the selection committee a little bit about yourself, your interests, and your capabilities.

(Limit 200 words)

I am a control systems engineer who applies deep learning concepts in solving nonlinear dynamical control systems problems. My work explores better model representation using state-of-the-art neural network function approximators to determine accurate system models, for example in adaptive control or model predictive control of complex nonlinear systems. My background is in Physics and Control theory and I spend my PhD research exploring better ways of automating motion alignment correction systems in clinical cancer radiotherapy of malignant cancers of the head and neck region. The novelty of my work includes the design and use of soft robots with morphological computation properties to dynamically adjust patient motion along desired degrees of freedom during cancer radiotherapy treatment. As these soft actuators are nonlinear, a lot of effort goes into formulating the model properties of the hardware in order to obtain an effective controller that can deliver the required sub-millimeter and sub-degree accuracy. Owing to the recent advances in sequential deep learning frameworks in terms of their accuracy and precision in generating powerful models for tasks including speech recognition and machine language translation, I leverage on these technologies to create dynamic models of the patient testbed and to design appropriate adaptive controllers to scale.

5.2 Your Work and/or Research Concept Note
Tells us about the research and/or work that you do. Why is it important? What aspects of it involve Planetary Science, Heliophysics, Exogeology, Data Science or Computer Science?
Most importantly, what are your ideas on how AI technologies can be applied to either Space Weather, ISRU Prospecting and Planetary Defense? Either in terms of better information gathering, better insight or better decisions.
(Limit 500 words)

In radiotherapy treatment of cancer of the head and neck (H&N) region, patients are typically positioned in a supine manner on a 6-DOF robotic couch for motion alignment with respect to an incident radiation which is used to target malignant tumors. As such, the precision of delivery of the radiation dose to target tumor is extremely important. Target miss in dosimetry angle or position arising from patient have been known to cause eczema, brain complications and the exposure of organs at risks. To prevent the patient from drifting from pre-calibrated pose on the 6-DOF robotic treatment couch, clinicians fixate metallic rings/frames or elastic plastic masks on the patient's head and neck region so that involuntary motion by the patient is greatly minimized. But the use of such rings or masks have undesirable effects such as attenuating the radiation beam (thus minimizing incident dose and treatment efficacy) or making the patient uncomfortable. The majority of such masks employed do not compensate for real-time patient deviation from planned targets. To compensate for such drifts, I have formulated a neuro-adaptive controller for a network of compliant soft-robot systems to automatically move the patient's head and neck to desired pose based on a learning based finite-state machine.

The idea is that by actuating elastomeric polymer enclosures that inflate or deflate based on the amount of air that is sent into them or by the amount of pressure that is exerted on them by a human-body part (such as head or neck), we can achieve a desired level of pose in frameless or maskless radiotherapy without sacrificing patient comfort or treatment efficacy as existing technologies allow. This is a revolutionizing approach to the current way frameless radiotherapy is practiced. My solution is the only one so far that achieves desired actuation in closed-loop control and in real time without sacrificing time, treatment efficiency

or patient comfort -- all based on a data-driven modeling approach and a mathematically proven stable neural-network based controller to compensate for the dynamics of the system.

I have expertise in modeling physical systems, biomedical systems using a supervised learning approach with domains spanning classical system identification, deep learning, machine learning and adaptive control theory. I believe my skills would be relevant to the challenges the Frontier Development Labs is trying to solve with respect to leveraging on AI technologies to solve the important problems facing the planet and outer space. The nonlinear autoregressive moving average with exogenous inputs (NARMAX) method, popularly used in system identification techniques has been successful in the modeling and analysis of geospatial data,particularly in the understanding of space and weather forecasts. With the error reduction ratio, a user has to find the Lipschitz basis functions that can well represent the underlying model through an extensive expert-driven process. I am interested in using recursive Bayesian neural networks, deep learning models and directed acyclic graphs to further simplify such modeling methods in geospace data analysis. In a Monte Carlo framework, whereby patterns in space weather data are formulated in a probabilistic Bayesian setting, and minding the designing stability theorems for such networks, we can automate the pattern discovery and analysis in complex systems without resolving to complicated methods such as NARMAX models currently allow. My goal is to explore better model representation by designing efficient algorithms for complex systems analysis and control.

5.3 Collaboration and Cross-Disciplinary Work
Frontier Development Lab is a an applied research accelerator requiring cross-disciplinary work with peers from different knowledge and skill domains. As such, your ability to work in a team is critical to your success in our Lab. Please attach a short essay that explores this idea and provide insights based on experience that you have had. Include examples of things you have prototyped, developed, coded or hacked in a team.

I love cross-disciplinary work. For example, I collaborate with the radiation oncology department at the University of Texas Southwestern Medical Center helping them to find simplified control systems solutions to pose correcting systems during clinical cancer radiotherapy treatments.  So far, my investigations have led me to realize the power of neural networks in formulating the nonlinear model of a desired reference for an  adjustable system (in a model-reference adaptive system setting) during cancer radiotherapy. My results and feedback from my collaborators suggest I am doing something right. I intend to carry on with this spirit of excellence when I join the frontier development labs in the summer.

In the research lab where I am enrolled for my PhD, I work with colleagues involved in distributed formation control of multi-agent systems. My role is to understudy the algorithms they formulate, and write implementations to their algorithms in fast procedural and object oriented programming languages in order to scale the algorithms to real-time implementation. One of my joint work with them would be appearing at the next International Conference on Robotics and Automation (ICRA).

Last year, as an intern at Amazon Robotics LLC, I worked across departments helping in the design of SLAM software and hardware integration of a speech and LiDAR-based navigation system into a mobile robot. I believe my previous experiences working in a cross-disciplinarian fashion would be useful in my collaborations at the Frontier Development Lab.

(Limit 200 words)

Recommendations
If you have been recommended to apply for Frontier Development Labs by an industry

professional, please fill in their name here.

Recommender Name

First Name: Mikhail

Last Name: Balikhin

Letter of Recommendation
Whilst not mandatory, a letter of recommendation from a professional individual recognized within the Planetary Science or Machine Learning Community will help us evaluate your application. Please be thoughtful when selecting your references, and make sure that you choose at least one person who knows you well personally and one that knows you professionally in your current position. Although not mandatory, references from individuals recognized within the Planetary Science or Machine Learning Community would be preferred.

Please fill in their email address here, and we will send them a recommendation form to fill out.

Recommender E-mail