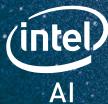




FRONTIER  
DEVELOPMENT  
LAB

# 2018 HANDBOOK



Google Cloud



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AI RESEARCH FOR SPACE EXPLORATION  
AND ALL HUMANKIND

—  
8 WEEKS AT NASA AMES & SETI INSTITUTE

SETI  
INSTITUTE

# WELCOME TO FDL



## EUGENE L. TU CENTER DIRECTOR, NASA AMES RESEARCH CENTER

NASA Ames Research Center is pleased to once again support the NASA Frontier Development Lab (FDL) 2018 program. We are excited about FDL's commitment to the advancement of artificial intelligence and machine learning tools applied to space science, discovery and development. The broad level of support by Silicon Valley commercial industry partners is very inspiring, and we look forward to FDL researchers thriving and producing great work during their time at Ames this summer.



## BILL DIAMOND PRESIDENT & CEO, THE SETI INSTITUTE

The SETI Institute is proud to be hosting NASA's Frontier Development Lab for its third iteration, which explores the application of deep learning techniques to mission-critical science questions, with the objective of achieving accelerated research results. It is particularly exciting to be expanding FDL 3.0 beyond Space Weather and Space Resources to include new challenges in Astrobiology and Exoplanet detection. SETI Institute scientists will join research colleagues from around the world in providing mentoring for FDL teams and we are excited about the prospects for another breakthrough program!



**DANIEL J. RASKY  
CHIEF, SPACE PORTAL OFFICE NASA ARC**

NASA Ames is delighted to be bringing back the summer study series that we started back in the 1970's and we are excited about the results that will come from this 8 week effort from such a talented group of participants.



**DEBBIE KOLYER  
DIRECTOR, GRANTS ADMINISTRATION, SETI INSTITUTE  
ARMINA SAROIAN,  
DIRECTOR, HUMAN RESOURCES, SETI INSTITUTE**

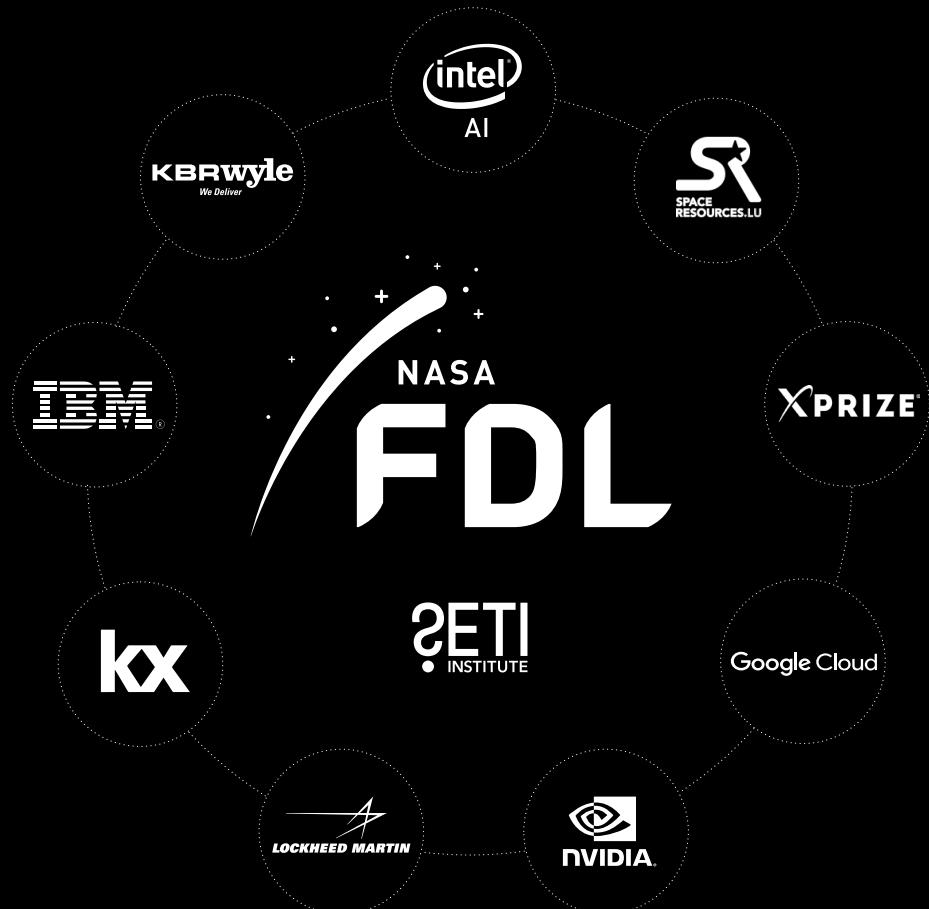
Congratulations and welcome! In partnership with our sponsors, the SETI Institute proudly hosts FDL 3.0. As future leaders in your fields of expertise, you will be working in interdisciplinary teams and collaborating with stellar researchers towards the goal of implementing AI techniques to resolve scientific problems. We are looking forward to your participation and wish you an invigorating, stimulating, and rewarding experience.



**JAMES PARR  
FDL DIRECTOR**

I'd like to extend a warm welcome to all our researchers and partners for our third FDL this Summer. In my career, I have never seen such firepower (both intellectual and computational) gathered together around an enrolling cause. It is not an understatement to say that this year's challenges have potential to affect every human being in the solar system and for that I would also like to say thank you on behalf of the FDL Steering Team. I wish you all an inspirational FDL 2018.

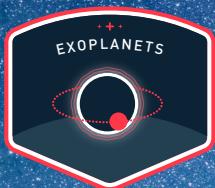
# THANKS TO OUR PARTNERS



## RESEARCH PARTNERS







# FDL FACES



**JAMES PARR**  
FDL DIRECTOR



**BILL DIAMOND**  
CEO, THE SETI INSTITUTE



**SARA JENNINGS**  
FDL PRODUCER



**DEBBIE KOLYER**  
DIRECTOR OF GRANTS  
ADMINISTRATION  
THE SETI INSTITUTE



**ARMINA SAROIAN**  
DIRECTOR OF  
HUMAN RESOURCES,  
THE SETI INSTITUTE



**GRAHAM MACKINTOSH**  
EXECUTIVE PROJECT MANAGER



**DAN RASKY**  
CHIEF SPACE PORTAL,  
NASA



**LIIKA GUHATHAKURTA**  
LEAD SCIENTIST,  
NEW INITIATIVES, NASA



**SHYLA SPICER**  
FDL ASSOCIATE  
PRODUCER



**LISA VESTAL**  
PROJECT COORDINATOR,  
NASA SPACE PORTAL



**REBECCA McDONALD**  
COMMUNICATIONS DIRECTOR,  
THE SETI INSTITUTE



**BRUCE PITTMAN**  
CHIEF SYSTEMS ENGINEER,  
NASA SPACE PORTAL



**JONATHAN KNOWLES**  
FDL IDEATION DIRECTOR



**ERIC DAHLSTROM**  
FDL FACILITATOR



**ALISON LOWNDES**  
ARTIFICIAL INTELLIGENCE  
DEVELOPER RELATIONS, NVIDIA



**LEO SILVERBERG**  
DIGITAL LIAISON

# FROM OUR PARTNERS

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"NASA Frontier Development Lab has allowed Intel to apply our AI technologies in a meaningful and inspiring way. The accelerated interdisciplinary approach brings innovative solutions to some of the greatest challenges facing space science and exploration today, and allows us to share this work with the world."

**BRIAN KRZANICH, CEO, INTEL CORPORATION**

"We are delighted to be working with NASA FDL's other core technology partners to create meaningful solutions."

**BRIAN CONLON, CHIEF EXECUTIVE OFFICER OF KX**

"IBM is excited to be a sponsor of the Frontier Development Lab and to participate in the innovative progress being made in the application of artificial intelligence technology to space science problems. Maintaining leadership in emerging technologies, such as Deep Learning and quantum computing, is central to IBM's strategy, so working with the FDL researchers to tackle problems with demanding computing requirements is a natural fit; it helps IBM to push the boundaries of our tools and validate our commercial solutions for the broader market. Moreover, the scientific objectives of the FDL program are intuitively inspiring, such as improving our understanding of environmental trends and solving problems which are critical to the success of mankind's exploration of space. These goals are well aligned with IBM's long and principled history of playing a central role in innovation that matters to society. We look forward to seeing the FDL program continue to expand in both scope and impact."

**MAC DEVINE, VICE PRESIDENT & CTO,  
IBM WATSON CLOUD DIVISION, IBM CORPORATION**



“NVIDIA remains proud to support the Frontier Development Laboratory. We were there at its origin, enabling teams to harness artificial intelligence and to accelerate research within the many fields of planetary defense. What greater role could we give to our revolutionary new computing platform than to augment human exploration across the universe, while protecting those here on Earth.”

**JEN-HSUN HUANG, PRESIDENT & CEO, NVIDIA CORPORATION**

“FDL is disrupting how we do scientific discovery and data analytics for space science missions. Even though NASA’s Solar Dynamics Observatory (SDO) is the world’s most widely used resource for heliophysics science and space weather monitoring, the full richness of the data remains to be exploited. FDL bridges the gap between the AI/ML and the science communities. Through FDL, scientists are learning how to use the latest AI/ML techniques to discover patterns and relations in our data. We are using the latest hardware and software stacks to accelerate science. In return, the AI/ML experts at FDL get first-hand experience in contributing to space science and exploration.”

**MARK CHEUNG, PHYSICIST AT LOCKHEED MARTIN AND PI FOR THE ATMOSPHERIC IMAGING ASSEMBLY INSTRUMENT ONBOARD SDO**

# BRIEFING:

## ARTIFICIAL INTELLIGENCE FOR SPACE EXPLORATION AND ALL HUMANKIND.

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**A few years ago, we were asked by the Office the Chief Technologist at NASA HQ to help develop a portfolio of 'Grand Challenges' that could provide a focus for a bold new approach to engaging with unconventional partners, academia and the commercial sector.**

The Frontier Development Lab is the descendant of that vision, grounded in the essential truth that a fundamental engine of progress is the collision of disciplines - supported by the key ingredients of sharp questions, rapid iteration, and a culture of possibility - not to mention the fastest state-of-the-art AI compute from commercial partners.

That formula is now taking us into our third year, bigger and bolder than ever before. **This year, NASA and the SETI Institute are joined by the foremost names in commercial AI, including Intel, IBM, KX Systems, Nvidia and Google, as well as critical players in the commercialization of space - Space Resources Luxembourg, Lockheed Martin, KBRWyle and XPRIZE.**

This year we're also delighted to be joined by international partners. A sister FDL, in partnership with the European Space Agency (ESA), the UK's Space Applications Catapult and Oxford University, will be based in Europe, run in parallel to the US program. Our hope is to foster the same spirit of international collaboration that has promoted excellence in previous years. We encourage everyone to reach out and get involved with the FDL Europe team.





Over the past two years, FDL has successfully demonstrated the potential for interdisciplinary AI approaches to tackle challenges in planetary defense, space weather and lunar prospecting. FDL's researchers have helped move the state-of-the-art in using AI to predict solar activity, map the lunar poles, build 3D shape models of potentially hazardous asteroids, discover uncategorized meteor showers and determine the efficacy of asteroid mitigation strategies.

This year, FDL continues its work on space weather and space resources, and expands its work to include challenges in astrobiology, exoplanets, and Earth

observation (the last in Europe with ESA). We also define stretch goals in AI applications such as verification and explainability.

We welcome you to the FDL community and thank you for your willingness to give your mind and spirit to these important problems of relevance to both our future in space and our collective wellbeing here on Earth.

**We're looking forward to some fascinating discussions over the Summer.**

# THE CHALLENGES

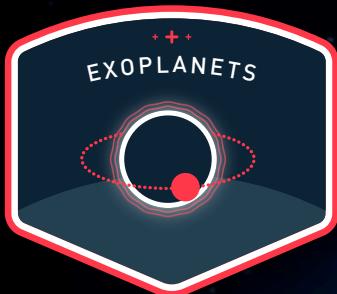
## ASTROBIOLOGY CHALLENGES



CHALLENGE 01  
**UNDERSTANDING WHAT IS  
UNIVERSALLY POSSIBLE FOR LIFE.**

CHALLENGE 02  
**FROM BIOHINTS TO EVIDENCE OF  
LIFE: POSSIBLE METABOLISMS  
WITHIN EXTRATERRESTRIAL  
ENVIRONMENTAL SUBSTRATES**

## EXOPLANETS CHALLENGE



CHALLENGE 01  
**INCREASE THE EFFICACY AND YIELD  
OF EXOPLANET DETECTION FROM  
TESS AND CODIFY THE PROCESS  
OF AI DERIVED DISCOVERY**

## SPACE WEATHER CHALLENGES



### CHALLENGE 01

**IMPROVE IONOSPHERIC MODELS  
USING GLOBAL NAVIGATION  
SATELLITE SYSTEM SIGNAL DATA**

### CHALLENGE 02

**PREDICTING SOLAR SPECTRAL  
IRRADIANCE FROM SDO/AIA  
OBSERVATIONS**

## SPACE RESOURCES CHALLENGES



### CHALLENGE 01

**AUTONOMOUS ROUTE PLANNING  
AND COOPERATIVE PLATFORMS**

### CHALLENGE 02

**LOCALIZATION: MERGING ORBITAL  
MAPS WITH SURFACE-PERSPECTIVE  
IMAGERY**

# AI TECHNICAL COMMITTEE

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## Co-chairs:



AI MENTOR  
**CHEYDY RAISSI**  
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Chedy Raissi is a research scientist (chargé de recherche) at the Institut National de Recherche en Informatique et en Automatique (INRIA), France. Chedy received his PhD in Computer Science from the University of Montpellier and the Ecole des Mines d'Ales in July 2008. Prior to joining INRIA (France), Chedy worked as a research fellow (post-doctoral researcher) at the National University of Singapore on privacy-preserving data mining with emphasis on the healthcare field. His current research focuses on developing efficient novel pattern mining techniques and the application of machine learning and data mining approaches to various multidisciplinary areas.



AI MENTOR  
**YARIN GAL**  
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Yarin is an Associate Professor in Machine Learning at the University of Oxford. He was previously a Research Fellow at the University of Cambridge and part-time Fellow at the Alan Turing Institute, the UK's national institute for data science. He obtained his PhD from the Cambridge machine learning group, working with Prof Zoubin Ghahramani and funded by the Google Europe Doctoral Fellowship.

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### **Committee members:**

**ALISON LOWNDES,**  
NVIDIA

**ATILIM GUNES BAYDIN,**  
UNIVERSITY OF OXFORD

**IAN GOODFELLOW,**  
GOOGLE

**FRANCK MARCHIS,**  
SETI INSTITUTE

**FRANCOIS CHOLLET,**  
GOOGLE

**SIDDHA GANJU,**  
DEEPPVISION

**GREG RENARD,**  
XBRAIN

**NAGIB HAKIM,**  
INTEL

**LORIEN PRATT,**  
QUANTELLIA

**AMIR BANIFATEMI,**  
XPRIZE

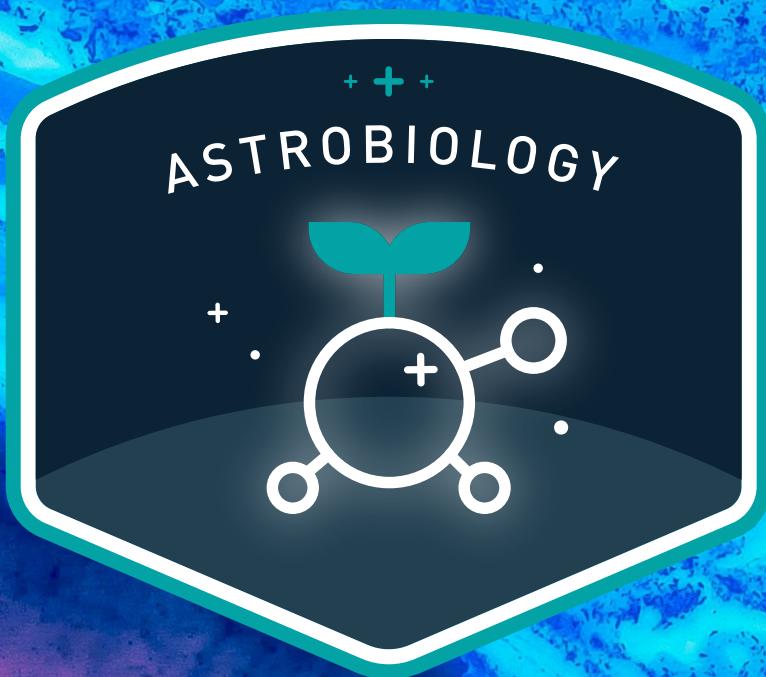
**MARK CHEUNG,**  
LOCKHEED MARTIN

**NAEEM ALTAF,**  
IBM

**AMIR KHOSROWSHAHİ,**  
INTEL

**TROY HERNANDEZ,**  
IBM





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Google Cloud

# 01



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## UNDERSTANDING WHAT IS UNIVERSALLY POSSIBLE FOR LIFE

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Can we anticipate exotic metabolic pathways using unsupervised (non human bias) machine learning approaches with a view to determining the chemistry of a biosphere - and ultimately ecological signatures that may suggest life, but 'not as we know it'?

## ASTROBIOLOGY 01 // MENTORS

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PLANETARY MENTOR  
**CHRIS KEMPES**  
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Chris Kempes is a scientist working at the intersection of physics, biology, and the earth sciences. Using mathematical and computational techniques, he studies how simple theoretical principles inform a variety of phenomena ranging from major evolutionary life-history transitions, to the biogeography of plant traits, to the organization of bacterial communities. He is particularly interested in biological architecture as a mediator between physiology and the local environment.



AI MENTOR  
**ANAMARIA BEREA**  
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Anamaria is a research assistant professor with the Complex Adaptive Systems and Data Analytics Laboratory, College of Engineering and Computer Science, University of Central Florida. She has a dual PhD in economics and computational social science. Her current research is focused on the emergence of communication in biological and social networks. She applies theories and methods from economics, complex systems and information theory to reinterpret historical, anthropological and biological evidence regarding fundamental aspects of communication. She was one of the data scientists taking part in the NASA/SETI Frontier Development Lab (2017) in the Solar Storm Predictions team, and she is the author of the book "Emergence of Communication in Socio- Biological Networks" (Springer, 2018).

## ASTROBIOLOGY 01 // MENTORS

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**PLANETARY MENTOR  
NATHALIE CABROL**

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Nathalie is an astrobiologist and an explorer, and the Director of the Carl Sagan Center for Research at the SETI Institute (SI). In addition to framing the scientific vision at the SI, she leads projects in planetary science and astrobiology, develops science exploration strategies for Mars, Titan, and the Outer Solar System icy moons, and designs robotic field experiments. She explores high altitude lakes in the Andes where environmental conditions are analogous to early Mars. With her team, she documents life's adaptation to extreme environments, the effect of rapid climate change on lake ecosystems and habitats, its geobiological signatures, and its relevance to planetary exploration.

**Helping both teams.**



**PLANETARY MENTOR  
CLAIRE MCLEAN**

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Claire- Marie McLean completed her PhD at the University of Geneva studying the origins of life and complexity, in particular the role of non-equilibrium thermodynamics in evolutionary processes. Since then, she has been working in astrobiology with a particular focus on the geochemical and geophysical barriers to life on the icy moons of the outer solar system and has also worked on the ESA led International Space station experiment BioRock.

**Helping both teams.**



AI MENTOR  
**MASSIMO MASCARO**  
[massy@google.com](mailto:massy@google.com)

Massimo is a Technical Director of Applied AI in the Office of the CTO for Google Cloud. In this role, he helps VIP customers reimagine the production of goods and services and how value is exchanged in free markets by leveraging the power of AI and the Google technologies that enable it.

Prior to Google he worked at Intuit where he founded and led the data science group as chief data scientist and director of data engineering for the consumer group. In that role he was responsible for all TurboTax analytics data ingestion systems and worked on many challenging but rewarding predictive analytics and personalization features that power TurboTax and help tens of millions of people do their taxes more easily. Before Intuit, Massimo worked as lead of the R&D group of Intellisis, a small San Diego startup that builds advanced speech processing software for various US government and defense entities.

Massimo started in theoretical physics where, as part of his masters degree, he studied the dynamics of large recurrent neural networks. He then continued to work as a postdoc at the University of Chicago on applications of neural networks to computer vision problems, in particular in the use of attention to disentangle the problem of object detection and object recognition. In 2001, he took some of the results of his research and founded a startup in Europe, Wolf Solutions, successfully commercializing ICR (Intelligent Character Recognition) software for various European banks and for the Italian Postal Service. After the acquisition of that company, Massimo worked 6 years at Microsoft first in the High Performance Computing team and then in the core ranking team for the newly formed Bing search engine.

**Helping both teams.**

## ASTROBIOLOGY 01 // MENTORS

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PLANETARY MENTOR  
**DANIEL ANGERHAUSEN**  
[daniel.angerhausen@gmail.com](mailto:daniel.angerhausen@gmail.com)

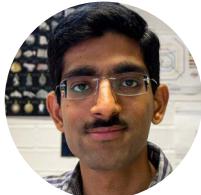
Daniel Angerhausen is an astrophysicist at the Center for Space Habitability at Bern University. The former NASA postdoctoral fellow is also founder and CEO of the Science Communication start up 'Explainables' a diverse team of highly qualified young communicators from all over the globe. On his search for planets around other stars Daniel already flew five missions in the NASA airborne telescope SOFIA. Daniel plays Sepaktakraw, an artistic footvolleyball game and competed several times at World Championships in South East Asia.

Helping both teams.

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## ASTROBIOLOGY 01 // MEET THE TEAM

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**ADITYA CHOPRA**  
PLANETARY SCIENTIST

Aditya (Adi) Chopra is an Astrobiology & Planetary Science Postdoctoral Fellow at the Australian National University. His research interests include using the elemental composition of life forms and their environments to study the origin and the evolution of life. He also investigates the astrophysical, geochemical and biological constraints on planetary habitability. He is currently investigating the role of biological regulation in maintaining a liquid water inventory on rocky planets over billions of years. He is also developing an online Astrobiology EdX course. He completed his undergraduate degree in chemistry at the University of Western Australia. He graduated with 1st class Honours in Astronomy and a PhD in Earth Sciences from the Australian National University. He was a visiting Postdoctoral Research Fellow at the University of Hawaii and the University of Washington. He enjoys sharing his passion for science through print, radio and online media, public lectures and partnerships with schools.



**AARON BELL**  
COMPUTER SCIENTIST

Aaron C. Bell is a recent PhD graduate and Visiting Researcher at the U. Tokyo. He is transitioning from astrophysics to the world of machine learning. Especially interested in projects that tackle machine learning together with scientific, infrastructure, or sustainability data.



## **WILLIAM FAWCETT** PLANETARY SCIENTIST

Will is a research associate in particle physics at the University of Cambridge. Using data from the Large Hadron Collider as CERN, he is searching for new physics in the form of new fundamental particles. If discovered, these particles could help answer some of the deepest questions in physics. In his research, he makes use of machine learning techniques to sift through the large volumes of data produced by the LHC.



## **RODD TALEBI** COMPUTER SCIENTIST

Rodd Talebi is a full-time Research Scientist at Georgia Tech Research Institute (GTRI) and a part-time student working toward his PhD in Machine Learning. His team at GTRI specializes in multi-objective genetic programming for algorithm design, and they teach an undergraduate class to use and develop their framework for genetic programming. Prior to living in Atlanta, Rodd spent some time in Los Angeles, earning a BS in Applied Mathematics and in Astrophysics from the University of California Los Angeles. He recently completed his first year as head coach for the club women's rowing team on campus.

# 02



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## FROM BIOHINTS TO EVIDENCE OF LIFE: POSSIBLE METABOLISMS WITHIN EXTRATERRESTRIAL ENVIRONMENTAL SUBSTRATES

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Extraterrestrial environments may have coevolved a broad range of alternative life processes markedly different to those we observe on Earth. Can we deploy AI techniques to generate an extended parameter space for possible metabolisms based on given (observed) environmental conditions and substrates?

## ASTROBIOLOGY 02 // MENTORS

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### PLANETARY MENTOR **SHAWN DOMAGAL GOLDMAN**

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Shawn Domagal-Goldman is the branch chief of Planetary Systems Laboratory at NASA's Goddard Space Flight Center in Greenbelt, MD. Dr. Domagal-Goldman is an astrobiologist that focuses on comparative planetology. As a member of multiple interdisciplinary teams, he simulates the atmospheres of other worlds, including those of ancient Earth, modern Mars, ancient Mars, and exoplanets. He utilizes the outputs from those simulations to interpret data from some of Earth's most ancient rocks, from the Mars Curiosity rover, and to simulate the capabilities of future space-based telescopes designed to look for life on exoplanets. Shawn is a collaborator by nature, and a member of many research and mission teams, including the Curiosity science team, the HabEx Science and Technology Definition Team, the Large UV-Optical-Infrared Surveyor (LUVOIR) Study Office, and is on multiple research teams in the Nexus for Exoplanet Systems Science (NExSS).



### PLANETARY MENTOR **GIADA ARNEY**

[giada.n.arney@nasa.gov](mailto:giada.n.arney@nasa.gov)

Giada is a research space scientist at NASA Goddard. She focuses on exoplanets, hazes, Venus, and astrobiology. She received a dual-title PhD in astronomy and astrobiology from the University of Washington. Her research has involved modeling and measuring properties of planets with an emphasis on worlds enshrouded by global cloud and haze layers because aerosols appear to be a common planetary phenomenon. She has a dual focus on both solar system bodies and on exoplanets. She has also extensive modeling experience of planetary atmospheres and have comprehensively simulated hazy Archean Earth with a coupled photochemical-climate model to study its atmospheric composition, climate, and habitability. Her current and near-future research focuses on modeling the atmospheric and climatic states of exoplanets, understanding the observational requirements to discriminate between different planetary states with current and future observatories, and re-visiting Venus with new observations.

## ASTROBIOLOGY 02 // MENTORS

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AI MENTOR

**ADAM COBB**

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Adam Cobb is a PhD student in Machine Learning at the University of Oxford. His interest lie in applying machine learning techniques in areas such as Signal Processing, Reinforcement Learning and Deep Learning. His Master's thesis focused on exoplanet detection in Kepler Mission Data using Gaussian processes to remove noise. His current research is on approximate inference in Bayesian neural networks and he has also previously worked on applying Bayesian non-parametric techniques to animal GPS data. Outside of his academic work, he enjoys running, swimming and playing soccer. He also likes to learn languages and has studied Chinese, German and French. As an avid space enthusiast, he looks forward to working with FDL to tackle challenging and worthwhile problems.



AI MENTOR  
**ATILIM GUNES BAYDIN**  
[gunes@robots.ox.ac.uk](mailto:gunes@robots.ox.ac.uk)

Atilim Gunes Baydin is a postdoctoral researcher at the University of Oxford, working at the intersection of generative modeling, probabilistic programming, and deep learning. His current work is on enabling efficient probabilistic inference in large-scale simulators in particle physics, in collaboration with CERN researchers. He co-organizes the Deep Learning for Physical Sciences workshop at the Neural Information Processing Systems (NIPS) conference, covering applications of machine learning to problems in physical sciences. He received his PhD in artificial intelligence from Universitat Autònoma de Barcelona in 2013. His research interests also include automatic differentiation, hyperparameter optimization, and evolutionary algorithms.

## ASTROBIOLOGY 02 // MEET THE TEAM

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**MICHAEL HIMES**  
PLANETARY SCIENTIST

Michael Himes is a first-year PhD student at the University of Central Florida studying exoplanetary atmospheres with Joseph Harrington. His research includes modeling light curves of exoplanet eclipse observations using the Spitzer Space Telescope, modeling planetary atmospheres with 1-D radiative transfer, and inferring atmospheric structure and composition of exoplanets via retrieval algorithms. In his free time, he enjoys hiking, playing tabla, and disc golfing.



**FRANK SOBOCZENSKI**  
COMPUTER SCIENTIST

Frank is a Computer Scientist at King's College London. His current research focuses on deep-learning and natural-language processing in the medical domain. He has previously worked in areas such as Human-Computer Interaction, Cyber-Security and Real-Time Systems in cooperation with the German Federal Police, GCHQ, Rapita Systems, INRIA, Barcelona Supercomputing Center & Airbus. He also served as a lead organizer of NASA Space Apps challenges and is working on AI projects with the National Space Society as well as on Hyperledger projects with IBM. Frank graduated from the Deggendorf Institute of Technology in cooperation with the German Research Center for Artificial Intelligence and received his PhD from the University of York for his work on reducing transcription errors (numerical and textual) of medical devices. He is a known R Ninja and particularly enjoys combining state-of-the-art technologies to solve challenging problems. Please do not leave any chocolate unattended in Frank's direct vicinity.



## SIMONE ZORZAN COMPUTER SCIENTIST

Currently Research Associate at the Luxembourg Institute of Science and Technology, Environmental Informatics group, he did research as a post-doc at the Center for Biomedical Computing in Verona and at the Babraham Institute in Cambridge (UK). His research activities focus on analyzing and visualizing biological data, revolving around multiple species, from bacteria to humans, passing through plants, and on research questions ranging from basic biology to applied translational medicine.

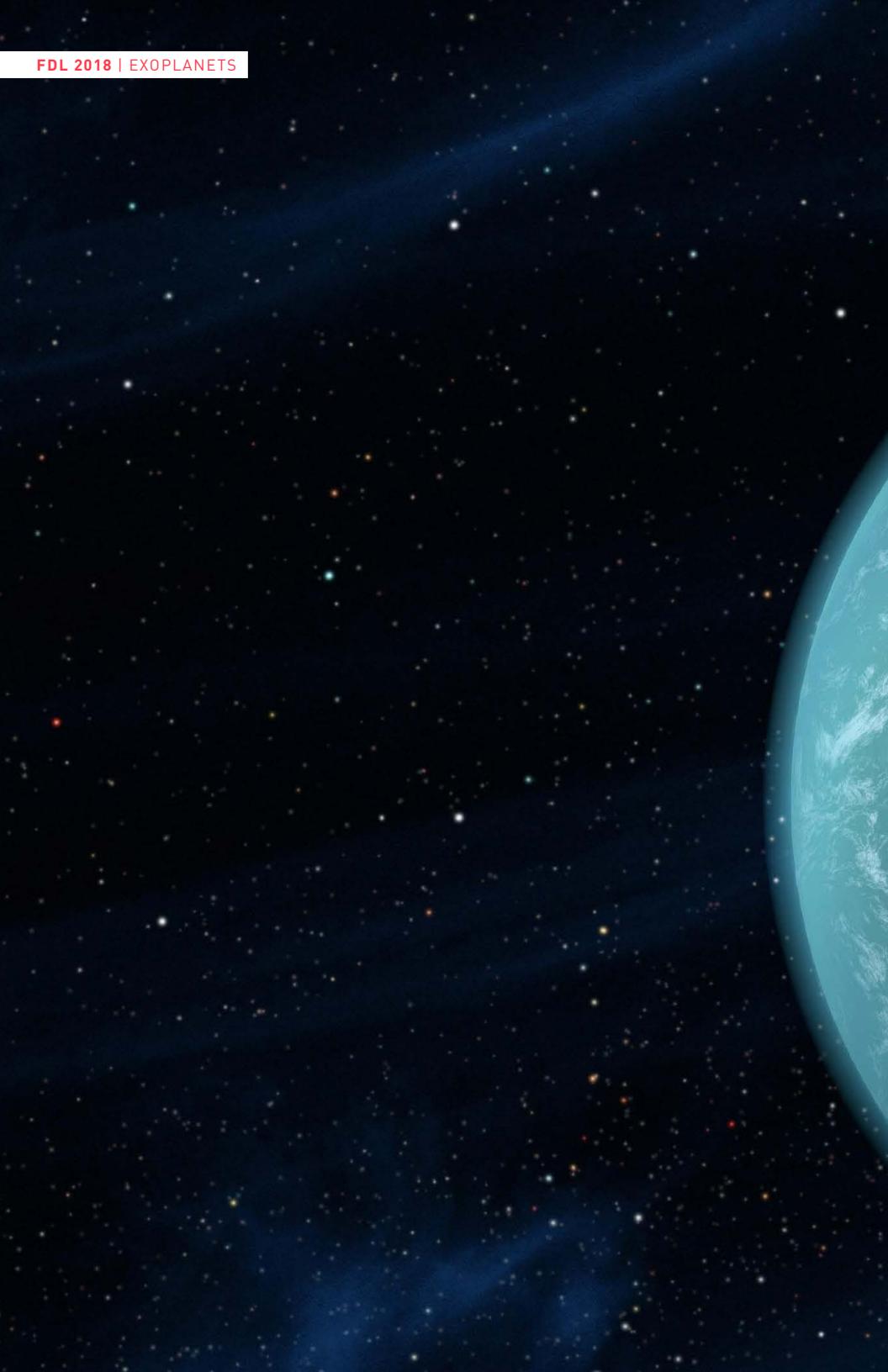
Italian living in France, when not in front of a PC, you might (briefly) find him practicing sport to get in a shape different from that of his chair, playing RPG with friends and debating the authentic recipes of Italian dishes.



## MOLLY O'BEIRNE PLANETARY SCIENTIST

Molly O'Beirne is more of a chemist than a biologist and more of a biologist than a geologist. Using molecular compounds that are associated with known processes (those in the business refer to these compounds as biomarkers) she learns how Earth has evolved through time - from the earliest iron and sulfur rich oceans, to the first signs of life, on to the rise of oxygen, to the demise of the dinosaurs, and all the way up and through modern day processes.

This approach can be described as organic geochemistry, geobiology, or biogeochemistry. No matter what you call it, the best part is being able to use her knowledge of chemistry (her first scientific love) to inform and answer compelling questions in geology and environmental science.



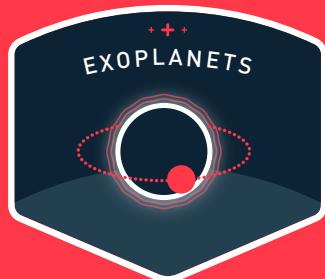
# EXOPLANETS



Google Cloud

kx

# 01



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## INCREASE THE EFFICACY AND YIELD OF EXOPLANET DETECTION FROM TESS AND CODIFY THE PROCESS OF AI DERIVED DISCOVERY

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TESS's mission to discern credible exoplanet signatures is made more demanding because of a mission time constraint, where follow-ups need to be identified every 27 days by manual analysis - an impossibly big challenge for humans in the time window available. Can AI help?

## EXOPLANETS 01 // MENTORS

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PLANETARY MENTOR

**JEFF SMITH**

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Dr. Jeffrey C. Smith is principal investigator for the SETI Institute Cooperative Agreements supporting science pipeline development for the Kepler and TESS missions. Dr. Smith began his academic passion in the field of Accelerator Physics. His Ph.D. thesis at Cornell University was on the design of the International Linear Collider (ILC), a 22 mile-long electron-positron accelerator that will complement the discoveries being made at the Large Hadron Collider (LHC) at CERN in Geneva, Switzerland. Jeff developed methods to preserve the small sizes of the beams, along with their polarization, over the full 22 mile long length of the machine. Jeff then joined the SLAC National Accelerator Laboratory at Stanford University to develop upgrade hardware for the LHC. After a successful career looking into the tiniest of inner-spaces Jeff decided to look up to the stars. Dr. Smith now develops data processing and planet detection algorithms for the Kepler and TESS Missions. Launched in March 2009, the Kepler Spacecraft has discovered thousands of planets and revolutionized our understanding of the universe. Eking out planet signals in the Kepler Data has proven to be a challenging and rewarding endeavor. To this end a sophisticated data processing pipeline has been developed to proceed from raw Kepler pixel data to planet signals. Looking forward to future discoveries, Dr. Smith is now involved with developing similar methods for the Transiting Exoplanet Survey Satellite (TESS), a new NASA Explorer Class planet finding mission launched in April, 2018.

## EXOPLANETS 01 // MENTORS

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### AI MENTOR **CHEDY RAISSI**

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Chedy Raissi is a research scientist (chargé de recherche) at the Institut National de Recherche en Informatique et en Automatique (INRIA), France. Chedy received his PhD in Computer Science from the University of Montpellier and the Ecole des Mines d'Ales in July 2008. Prior joining INRIA (France), Chedy worked as a research fellow (post-doctoral researcher) at the National University of Singapore on privacy-preserving data mining with emphasis on the healthcare field. His current research focuses on developing efficient novel pattern mining techniques and the application of machine learning and data mining approaches to various multidisciplinary areas.



### PLANETARY MENTOR **JON JENKINS**

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Dr. Jon Jenkins is Co-Investigator for Data Processing for both the Kepler Mission and the upcoming TESS Mission. He conducts research at NASA Ames Research Center on data processing and detection algorithms for discovering transiting extrasolar planets. Dr. Jenkins joined the Kepler team in 1995 to help develop the technology for Kepler before it was selected for flight in 2002. He led the design and development of the science processing pipeline for Kepler, which takes the data from raw pixels to the detection and initial characterization of transiting planet candidates. In February 2014, Dr. Jenkins joined NASA Ames Research Center to lead the effort to design and build a science processing center for NASA's newly selected TESS Mission which will perform an all-sky transit survey to identify the closest and best Earth-size and super-Earth-size planets for follow-up and characterization. Dr. Jenkins received NASA's Exceptional Technology Achievement Medal as well as NASA's prestigious Software of the Year Award in 2010 for his work on Kepler. He holds a Ph.D. in Electrical Engineering.



**PLANETARY MENTOR  
DOUGLAS CALDWELL**

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Douglas Caldwell is a research scientist at the SETI Institute and a co-investigator and the instrument scientist for NASA's Kepler Mission. He holds a bachelor's in physics from Carnegie-Mellon University and a Ph.D. in physics from Rensselaer Polytechnic Institute in New York, where he studied how stars form in differing galactic environments. Caldwell came to NASA Ames on a postdoctoral fellowship in 1998 where he switched from stars to planets, working with William Borucki on the Vulcan project, one of the first ground-based searches for transiting exoplanets. He then led an international team to continue the search from the South Pole in order to take advantage of the long winter nights. Caldwell joined the Kepler Mission in 2001 and was named Instrument Scientist in 2006.



**PLANETARY MENTOR  
HAMED VALIZADEGAN**

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Hamed is currently a senior machine learning scientist at NASA Ames Research center in California. He has been involved in data mining projects related to the Hubble Space telescope, Kepler mission and the International space station. Prior to joining NASA he completed a PhD in computer science at Michigan State University And worked as a postdoc on a NIH funded health informatics project at the University of Pittsburgh.

## EXOPLANETS 01 // MENTORS

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AI MENTOR  
**MASSIMO MASCARO**  
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Massimo is a Technical Director of Applied AI in the Office of the CTO for Google Cloud. In this role, he helps VIP customers reimagine the production of goods and services and how value is exchanged in free markets by leveraging the power of AI and the Google technologies that enable it.

Prior to Google he worked at Intuit where he founded and led the data science group as chief data scientist and director of data engineering for the consumer group. In that role he was responsible all TurboTax analytics data ingestion systems and worked on many challenging but rewarding predictive analytics and personalization features that power TurboTax and help tens of millions of people do their taxes more easily. Before Intuit, Massimo worked as lead of the R&D group of Intellisis, a small San Diego startup that builds advanced speech processing software for various US government and defense entities.

Massimo started in theoretical physics where, as part of his master degree, he studied the dynamics of large recurrent neural networks. He then continued to work as a postdoc at the University of Chicago on applications of neural networks to computer vision problems, in particular in the use of attention to disentangle the problem of object detection and object recognition. In 2001, he took some of the results of his research and founded a startup in Europe, Wolf Solutions, successfully commercializing ICR (Intelligent Character Recognition) software for various European banks and for the Italian Postal Service. After the acquisition of that company, Massimo worked 6 years at Microsoft first in the High Performance Computing team and then in the core ranking team for the newly formed Bing search engine.



**PLANETARY MENTOR  
DANIEL ANGERHAUSEN**

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Daniel Angerhausen is an Astrophysicist at the Center for Space Habitability at Bern University. The former NASA postdoctoral fellow is also founder and CEO of the Science Communication start up 'Explainables' a diverse team of highly qualified young communicators from all over the globe. On his search for planets around other stars Daniel already flew five missions in the NASA airborne telescope SOFIA. Daniel plays Sepaktakraw, an artistic footvolleyball game and competed several times at World Championships in South East Asia.

## EXOPLANETS 01 // MEET THE TEAM

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**MICHELE SASDELLI**  
COMPUTER SCIENTIST

Michele Sasdelli's original background is in physics. He studied and worked in three countries both in academic and industry environment. He was undergrad in Pisa, Italy with a prestigious scholarship. After graduation he moved to Germany for a PhD (graduated in 2015) at the Max Planck Institute and TUM where he explored the use of machine learning to study supernova spectra and photometry. He worked as a postdoc at the Astrophysics Research Institute in Liverpool, focussing on deep learning applications. He is now a research scientist at Cortexica Vision Systems, an AI company in London. During the last two years he focussed on implementing deep learning based algorithms for object detection, action recognition, object tracking, and segmentation in images and videos. His interests lie in fundamental machine learning questions for computer vision and astrophysics. He is a science enthusiast and firmly believes in cross-feeding between different research fields.



**MEGAN ANSDELL**  
PLANETARY SCIENTIST

Megan is currently a Postdoctoral Fellow at the University of California, Berkeley, with the Center for Integrative Planetary Sciences. She has a PhD in Astronomy from the University of Hawaii, where her thesis used large-scale surveys of protoplanetary disks to study planet formation as well as Kepler/K2 light curves to study young star variability. Megan has a penchant for interdisciplinary research; prior to her PhD, she acquired an MA in International Science and Technology Policy from the George Washington University in Washington, DC, where she specialized in Space Policy. She also has an MSc in Space Management from the International Space University in France, where she studied a variety of subjects related to space exploration. Her BSc in Astrophysics is from the University of St. Andrews in Scotland.



## HUGH OSBORN PLANETARY SCIENTIST

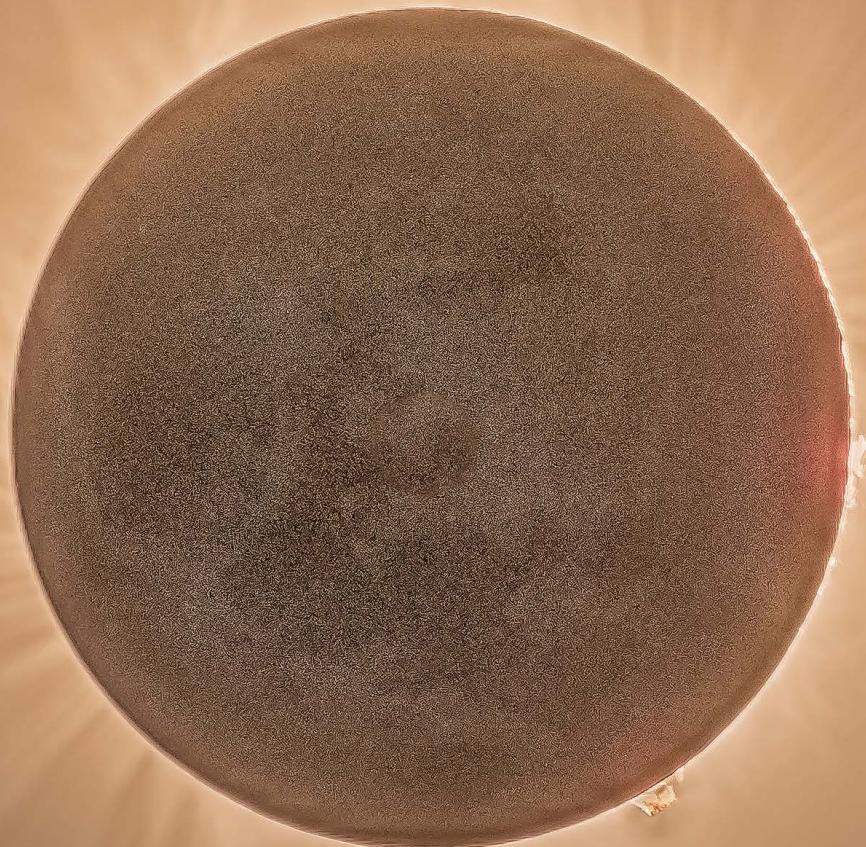
Hugh is a post-doctoral researcher in exoplanet astronomy at the Laboratoire d'Astrophysique de Marseille although, as a recently-arrived Brit, he still struggles to pronounce it correctly. He grew up in Norwich (UK) before heading to UCL to study an Earth Sciences degree that fused both planetary geophysics and astronomy. Putting the former into practice, he did a PhD in astronomy at the University of Warwick, using both ground-based and space-based telescopes to search for transiting exoplanets, especially those cooler worlds on long orbits. He continues some of that work in France, but also focusses on developing new techniques for the ranking of exoplanet candidates for ESA's future PLATO space telescope, including the application of Machine Learning techniques.



## YANI IONNOU COMPUTER SCIENTIST

Yani is finishing up his PhD in the Department of Engineering at the University of Cambridge, having defended in January. He was supervised by Professor Roberto Cipolla, head of the Computer Vision and Robotics group in the Machine Intelligence Lab, and Dr. Antonio Criminisi, a principal researcher at Microsoft Research, under a Microsoft Research PhD scholarship. Since October last year he has been working in a stealth self-driving startup in Cambridge.

His PhD focused on the effect of structure in learning deep neural networks, and their application to problems in computer vision. He has in the past worked on 3D computer vision, towards methods for processing and recognizing objects in large point clouds. Outside of research, he has worked on open source projects such as the Linux kernel and the Point Cloud Library (PCL)





# 01



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## IMPROVE IONOSPHERIC MODELS USING GLOBAL NAVIGATION SATELLITE SYSTEM SIGNAL DATA

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By using large volumes of historic data that has been collected on GNSS (Global Navigation Satellite System) this challenge proposes to train an AI model to turn GNSS signal scintillation data into a high fidelity instrument for analyzing the state of the ionosphere and correlating that with space weather.

## SPACE WEATHER 01 // MENTORS

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### HELIOPHYSICS MENTOR

### **RYAN MCGRANAGHAN**

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In May 2016, Ryan defended his Ph.D. at the University of Colorado Boulder in the Aerospace Engineering Sciences program. During his graduate career, he worked within both the Remote Sensing and Atmospheric Sciences Department and the Colorado Center for Astrodynamics Research (CCAR). Ryan also pursued collaborations away from the University of Colorado with the National Center for Atmospheric Research (NCAR), National Oceanic and Atmospheric Administration (NOAA), NASA Jet Propulsion Laboratory (JPL), and the Los Alamos National Labs (LANL). These collaborations have led to a strong and far-flung network and his current position as a postdoctoral research fellow at NASA's Jet Propulsion Laboratory in Pasadena, CA.



### HELIOPHYSICS MENTOR

### **ASTI N. BHATT**

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Asti N. Bhatt, Ph.D., is a Geospace Studies Research Engineer. She works to understand the physics of ionospheric plasma during auroral precipitation at high latitudes by using the SRI-operated Sondrestrom incoherent scatter radar facility in Kangerlussuaq, Greenland. Studying aurora using both radio and optical techniques provides unique insights into the amount of energy deposited into the earth's ionosphere during solar storms and resulting auroral precipitation. Bhatt also studies global scale ionospheric processes that span continents—in particular, the propagation of large-scale waves in the ionosphere in response to forcing from solar or lower atmospheric events.

## SPACE WEATHER 01 // MENTORS

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AI MENTOR

**SYLVESTER KACZMAREK**

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Sylvester Kaczmarek is an award-winning entrepreneur and product leader with over a decade of international, quality-driven IT industry experience. His expertise in business strategy, operations, and product strategy has brought leadership and financial growth to companies such as Viacom, GREE, Disney, Nickelodeon, BBC, and many more.

Improving the world through the use of modern technology has become his primary focus, and he is interested in using artificial intelligence (AI) to solve the world's biggest problems through a combination of humans and machines working together in integrated intelligence.

He has served as a board member, mentor and advisor to several accelerators and innovation centres, emerging technology startups, and VCs focused on enriching lives, bringing joy and innovation to everyone.



HELIOPHYSICS MENTOR

**ANDRÉS MUÑOZ-JARAMILLO**

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Andres is a Senior Research Scientist at the SouthWest Research Institute and a visiting scholar at UCAR's High Altitude Observatory (HAO) and the National Solar Observatory (NSO) in Boulder, Colorado. He is originally from Colombia, but has been living in the US since he came to study his PhD at Montana State University in 2005. He fell in love with solar physics thanks to NSF's research opportunities for undergraduates (REU) program (of which I was part in 2003). The main objective of his research is to understand (and predict) the solar magnetic cycle and its impact on solar variability, space climate, and terrestrial climate change.



**AI MENTOR  
ANAMARIA BEREÀ  
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Anamaria is a Research Assistant Professor with the Complex Adaptive Systems and Data Analytics Laboratory, College of Engineering and Computer Science, University of Central Florida). She has a dual PhD in economics (2010) and computational social science (2012) and her current research is focused on the emergence of communication in biological and social networks, by applying theories and methods from economics, complex systems and information theory to reinterpret historical, anthropological and biological evidence regarding fundamental aspects of communication. She was one of the data scientists part of the NASA/SETI Frontier Development Lab (2017) in the Solar Storm Predictions team and she is the author of the book "Emergence of Communication in Socio- Biological Networks", Springer, 2018.



**AI MENTOR  
VIJAY MANIKANDAN JANAKIRAMAN  
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Vijay Manikandan Janakiraman is a Research Scientist at NASA Ames Research Center (USRA). He Received a PhD in Mechanical Engineering from Univ. of Michigan and has more than 10 years of experience in data mining, neural nets and deep learning. He has experience researching data mining algorithms and applications to NASA problems involving high dimensional time series data, in addition to deep learning, anomaly detection, discovery of precursors, prediction and applications to Aviation safety and adverse weather.

## SPACE WEATHER 01 // MEET THE TEAM

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**KIBROM ABRAHA**  
HELIOPHYSICS SCIENTIST

Kibrom is a geoscientist who has studied GPS/GNSS geodesy. He has a master degree in satellite geodesy and recently (2018) received his PhD degree in engineering sciences with a focus on high precision multi-GNSS and error characteristics. His current research focuses on the use of high precision GPS/GNSS for long-term monitoring applications in the atmospheric and geosciences. Kibrom is also data science and analytics enthusiast with interests in big data management, data processing and time series analysis.



**KARTHIK VENKATARAMANI**  
COMPUTER SCIENTIST

Karthik Venkataramani received his MS and PhD in Electrical and Computer Engineering from Virginia Tech. He has worked on developing numerical models of the Earth's upper atmosphere with a specific interest in understanding the energetics of the processes that occur there. As part of a scientific mission from Virginia Tech, he has supported the deployment of autonomous space weather monitoring stations in Antarctica. He also helped launch the PolarNOx sounding rocket from Poker Flat, AK in 2017, which was designed to measure thermospheric nitric oxide densities in the polar night.



**LAURA HAYES**  
HELIOPHYSICSSCIENTIST

Laura is a final year postgraduate student working in the astrophysics research group at Trinity College Dublin, Ireland. Her research is based in the study of solar flares and space weather effects at Earth. Specifically, she focuses on understanding solar flare X-ray emission, the oscillatory signatures observed during flaring events, and how these observations can be used to determine physical processes operating in flaring sites in the Sun's atmosphere. She is passionate about developing new data analysis techniques and is interested in how machine learning and AI techniques can be applied to scientific data.



**DANIEL KUMAR**  
COMPUTER SCIENTIST

Daniel Kumar is a software engineer, most recently with IBM Watson (with previous internships at Google, Lockheed, and EMC). He earned undergraduate degrees in business and mathematics from UNC-Chapel Hill, and master's degrees with emphases on machine learning, computer security, and astrophysics from Oxford, UNC, and Cambridge (where he focused on Milky Way formation with Gaia-ESO data). He enjoys tennis, home repair, reading books, and the great indoors.

# 02



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## PREDICTING SOLAR SPECTRAL IRRADIANCE FROM SDO/AIA OBSERVATIONS

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The goal of this challenge is to develop an AI model which uses SDO/AIA images to predict solar spectral irradiance (SSI) a critical factor for determining the properties of the Earth's upper atmosphere, which can significantly disturb the upper atmosphere of the Earth and increase atmospheric drag on orbiting satellites.

## SPACE WEATHER 02 // MENTORS

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### HELIOPHYSICS MENTOR

**MENG JIN**

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Meng is a heliophysicist at Lockheed Martin Solar & Astrophysics Laboratory and SETI Institute. He received his doctorate in Space Physics & Scientific Computing from University of Michigan, Ann Arbor in 2014. His research focuses on the origin of space weather: solar activity in the form of coronal mass ejections (CMEs), CME-driven shocks, and solar energetic particle events. By combining numerical simulations and observations, he is trying to advance our understanding of the physical processes at work during the propagation of CMEs from the Sun through the heliosphere. His recent research activity extends to the exo-solar and exo-planetary systems to simulate their stellar winds and stellar CMEs as well as the influences on the habitability of the exo-planets. He was a former NASA Jack Eddy Fellow from 2014-2016.



### HELIOPHYSICS MENTOR

**MARK CHEUNG**

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Mark Cheung is an astrophysicist at Lockheed Martin Solar & Astrophysics Laboratory and Stanford University. His scientific interests cover the Sun, space weather, cool stars and plasmas and magnetic fields pervading the universe. He is the Principal Investigator for the Atmospheric Imaging Assembly on board NASA's Solar Dynamics Observatory. He loves having thousands of computers work for him.

## SPACE WEATHER 02 // MENTORS

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AI MENTOR  
**DAVID FORD FOUEY**  
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David Fouhey is a postdoctoral fellow at the University of California, Berkeley and will be joining University of Michigan as an Assistant Professor in Fall 2019. His research interests include computer vision and machine learning, with a particular focus on scene understanding. He received a Ph.D. in robotics in 2016 from Carnegie Mellon University where he was supported by NSF and NDSEG fellowships. He has spent time at the University of Oxford's Visual Geometry Group and at Microsoft Research.



AI MENTOR  
**GRAHAM MACKINTOSH**  
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Graham Mackintosh is a pioneer in the field of advanced analytics and has applied his thought leadership into multiple new domains for big data analysis, high performance cloud computing, AI and Deep Learning. As a member of IBM's Emerging Technology Group, he is currently spearheading the challenge of applying Apache Spark, deep learning methodologies, and other cloud services to address complex business and scientific analytic needs.

Mentor for both teams.



**AI MENTOR  
NAEEM ALTAF**

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Naeem is an IBM Distinguished Engineer, with experience leading and creating integrated solutions for customers using IBM and Non IBM Technologies for Enterprise Systems, Business Services and Energy Management. His background includes building enterprise architectures and designs, quality assurance and customer interaction. He has a deep interest in Managing and Monitoring Industrial Sector (Green Data Centers, Smarter Cell Towers, Smarter Buildings, Smarter Container Terminals, Oil & Gas, Mining), Data Analytics, Data Mining, Data Visualizations, Open Data and Cleaner Energy

**Mentor for both teams.**



**AI MENTOR  
SEAN MCGREGOR**

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Sean McGregor participated in the NASA FDL in 2017 as a member of the solar flare prediction team. His obsession is the development of tools and techniques for safe and interpretable deployment of intelligent systems, which led to the development of the FlareNet codebase as a system of code and conventions for physicist-computer scientist collaboration in deep learning solar research. In 2018 he joined the technical staff of Syntiant Corp, where he develops deep learning models and training pipelines for exotic hardware, including analog processors. Dr. McGregor defended his PhD in machine learning, visualization, and optimization in 2017 at Oregon State University with a focus on reinforcement learning for wildfire suppression policy. Outside his research and startup work, Sean serves on two Partnership on AI working groups and as the technical lead for the IBM Watson AI XPRIZE-- a \$5 million contest for solving Grand Challenges with artificial intelligence.

## SPACE WEATHER 02 // MEET THE TEAM

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**RICHARD GALVEZ**  
HELIOPHYSICS SCIENTIST

Richard Galvez is a Moore-Sloan Data Science Fellow at the Courant Institute of Mathematical Sciences (Center for Data Science) and Center for Cosmology and Particle Physics at New York University. He holds a Ph.D. from Syracuse University in Theoretical Cosmology and Particle Physics, and is originally from Miami, FL.

After Syracuse, Richard joined Vanderbilt University as a Fisk-Vanderbilt Bridge Postdoctoral Fellow, where he began to develop his research program at the interface between astrophysics and AI. At NYU he has expanded further into pure AI research, with a focus on algorithms, deep learning, and generative adversarial networks (GANs). Beyond his academic work, Richard has given a Ted talk on dark matter titled "What Exactly is Dark Matter, Anyway?" and completed a data science internship at Stitch Fix, one of the largest data science teams in industry. He also really enjoys exercise, electronic music, backpacking, handstands, and cacti.



**RAJAT THOMAS**  
COMPUTER SCIENTIST

Electronics and communication engineer, space scientist, astrophysicist, neuroscientist, data scientist; these are a few of the positions held by Rajat Thomas who recently joined a startup in Amsterdam as a deep learning engineer. He holds a B.S. in engineering from India, M.S. in space sciences from Sweden/Germany, PhD in computational astrophysics from The Netherlands. Rajat has worked in several countries around the world. Most recently he built deep learning algorithms for neuro-imaging analysis in psychiatry and for the solution of radiative transfer problems in cosmology. He also holds a position at the Academic Medical Hospital and a guest position at the department of computer science and informatics at the University of Amsterdam. In his spare time he is an avid traveller, a lover of good cuisine and a cricket player.



## PAUL WRIGHT HELIOPHYSICS SCIENTIST

Paul Wright is a final-year PhD student in Heliophysics at the University of Glasgow, UK. His scientific interests range from solar to stellar physics, and his PhD research has concentrated on the solar coronal heating problem. In particular, his research has involved obtaining and analysing pioneering observations of the X-ray Sun with NASA's Nuclear Spectroscopic Telescope Array (NuSTAR). His research has also utilised a wealth of time-series analysis techniques on the multi-thermal coronal observations obtained by NASA's Solar Dynamics Observatory, and he has used numerous methods to solve linear ill-posed inverse problems. Prior to his graduate studies, Paul completed his undergraduate master's degree in Physics with Astrophysics (with a Year Abroad) at the University of Southampton (UK).

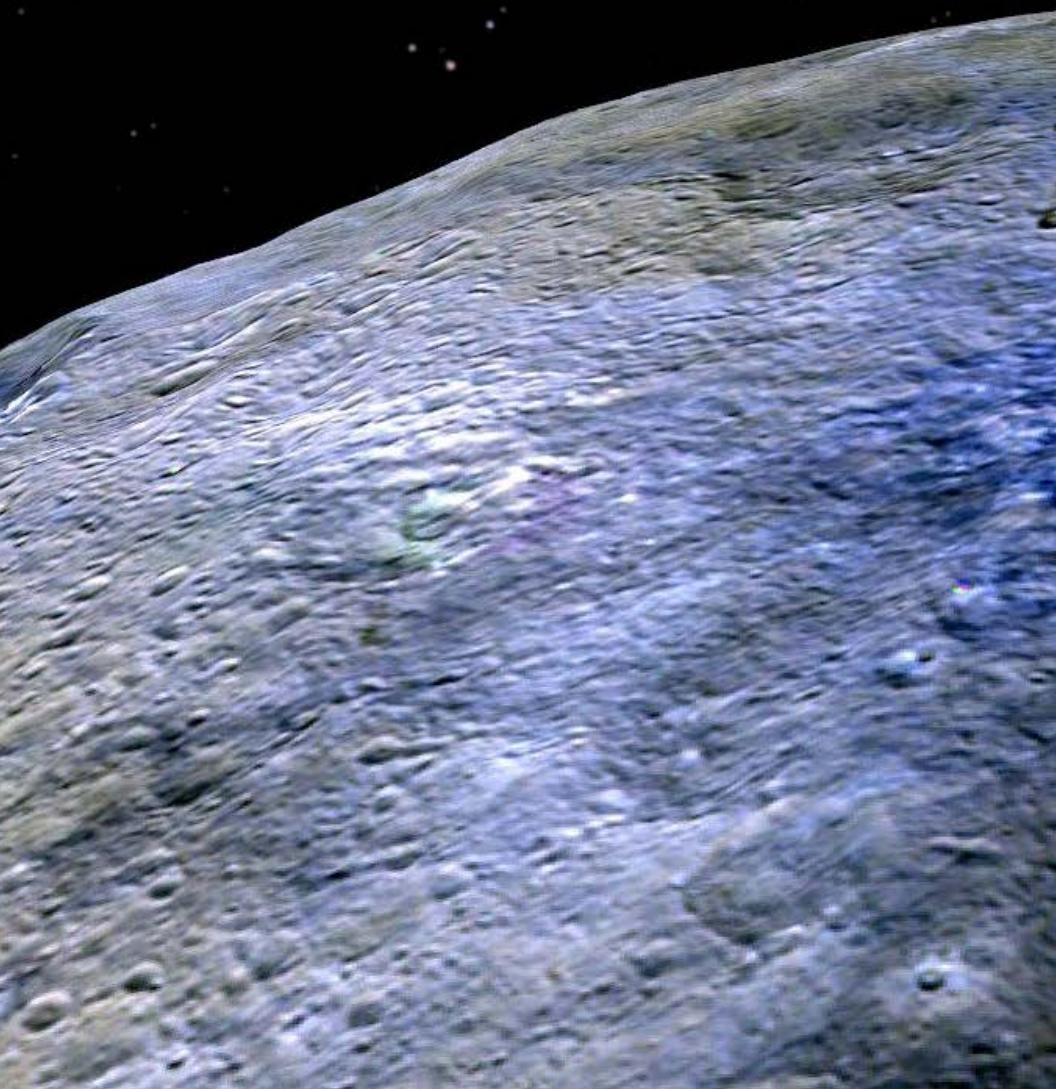


## ALEXANDRE SZENICER COMPUTER SCIENTIST

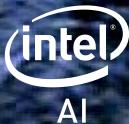
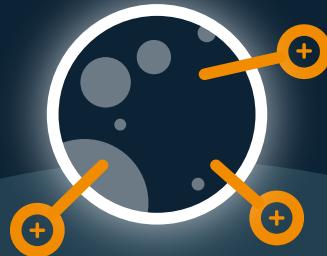
Alexandre Szenicer is a physicist with a very curious and open mind, who enjoys working in multidisciplinary settings and exploring different areas of science. Indeed, he believes that someone with strong mathematical and coding skills can tackle pretty much any problem, and this is what makes research so exciting to him.

Currently, he is doing a PhD at the University of Oxford, working in Computational Geophysics. What he loves about Geophysics is that it can combine theoretical and computational work with amazing field trips, like cruising the Indian Ocean or deploying instruments in the Caribbean. Imaging the Earth is a very computationally costly optimization task, and his research is about designing and implementing efficient numerical methods to render the problem tractable.

Being a big fan of science fiction for a long time, AI and Space have always been his passions since reading Asimov, Le Guin, and many others. He believes that the coming decades will be a turning point in the history of space exploration and robotics, with programs like FDL paving the way, and he is really excited to be a part of it.



# SPACE RESOURCES



# 01



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## AUTONOMOUS ROUTE PLANNING AND COOPERATIVE PLATFORMS

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Multi-agent system deployments have the potential to vastly improve upon conventional single-agent operations. Indirect cooperation, such as sharing knowledge and collaborative problem solving, offer to improve the robustness, capabilities and the overall value of Lunar missions.

## SPACE RESOURCES 01 // MENTORS

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### PLANETARY MENTOR **PHIL METZGER**

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Dr. Philip Metzger is a planetary physicist who recently retired from NASA's Kennedy Space Center, where he co-founded the KSC Swamp Works. He now is now at the University of Central Florida -- but still a part of the Swamp Works team -- performing research related to solar system exploration: predicting how rocket exhaust interacts with extraterrestrial soil, investigating the mechanics of soil, characterizing lunar and martian soil simulants, modeling the migration of volatiles on airless bodies, etc. While at NASA he led the Agency's work in rocket blast effects for human-class missions.



### PLANETARY MENTOR **J.L. GALACHE**

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J.L. Galache, PhD, is an asteroid astronomer turned NewSpace entrepreneur. He has designed and directed asteroid data projects with NASA's Frontier Development Lab and Oracle. At the Minor Planet Center (Harvard-Smithsonian Center for Astrophysics), J.L. was Acting Deputy Director, where he helped keep the world safe from killer asteroids. He has discussed asteroids as an expert commentator in every type of media: Radio, TV, documentaries, newspapers and online publications. He is an advisor to Deep Space Industries.

## SPACE RESOURCES 01 // MENTORS

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AI MENTOR  
**TIMOTHY SEABROOK**  
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Timothy graduated in MEng Intelligent & Robotic Systems at Lancaster University in 2014 and co-founded a Sharing Economy limited partnership in the same year. Since then, he has completed two years of DPhil CDT Autonomous Intelligent Machines and Systems at the University of Oxford and has begun developing his research into Distributed Learning of Dynamical Systems under Guarantees. Timothy's overarching objective is to develop responsible machine learning and robotic solutions to benefit humankind.



PLANETARY MENTOR  
**MARK SHIRLEY**  
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Mark is a Mission Operations Engineer at NASA Ames Research Center. Previously Mark has also worked as a member of the operations and science team for LADEE, as a software lead for Lunar Crater Sensing and Observation Satellite, and as a Research Staff at NASA Ames. Before joining NASA, Mark was part of the research staff at Xerox. He received his PhD in Computer Science from Massachusetts Institute of Technology.

Mentor for both teams.



SPECIALIST MENTOR  
**SHASHI JAIN**  
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Focused on Corporate Innovation and working in the Internet of Things (IoT) and 3D Printing. Early stage startup advisor, Professional Speaker, Teacher of entrepreneurship.

My work at Intelr uses Lean Startup, Customer Development and Design Thinking to build new IoT products. I work with startups to accelerate these innovations to market. I bring a diverse skill set and 20 years experience in business development, engineering integration, rapid prototyping, and community building to my work.

Mentor for both teams.



**AI MENTOR**  
**AMIR BANIFATEMI**  
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Amir Banifatemi is the Prize Lead of the IBM Watson AI XPRIZE. Prior to joining XPRIZE, Mr. Banifatemi began his career at the European Space Agency and then held executive positions at Airbus, AP-HP and the European Commission division for information society and media. He managed two venture capital funds and contributed to the formation of more than 10 startups with emphasis on Predictive Technologies, IoT, and Healthcare. Mr. Banifatemi is a guest lecturer and an adjunct MBA professor at UC Berkeley, Chapman University, Claremont McKenna College, UC Irvine, and HEC Paris.

He holds Masters degree in Electrical Engineering from the University of Technology of Compiègne, a Doctorate in System Design and Cognitive Sciences from the University Paris Descartes, as well as an MBA from HEC Paris.

**Mentor for both teams.**



**PLANETARY MENTOR**  
**BRUCE PITTMAN**  
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Bruce Pittman works at NASA as the Director of Flight Projects and Chief System Engineer in the NASA Space Portal and the Emerging Space Office at the NASA Ames Research Center. He is also the founder and president of Profit Engineering Technologies. Mr. Pittman supports programs ranging from suborbital human-tended research; orbital applications of the International Space Station and other orbiting commercial facilities; low cost, reliable access to space, reusable space infrastructure as well as cis-lunar commercialization. He has been involved in high technology project development, project management and system engineering in a variety of industries for over 30 years.

**Mentor for both teams.**

## SPACE RESOURCES 01 // MEET THE TEAM

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**ZAHI KAKISH**  
COMPUTER SCIENTIST

Zahi Kakish is a PhD Candidate in Mechanical Engineering at Arizona State University under Dr. Spring Berman. He works in the Autonomous Collective Systems Laboratory with a group of researchers spanning different fields to further research in collective robotic systems. His interests include Robotics, Swarm Intelligence, and Bio-inspiration.



**DREW BISCHEL**  
PLANETARY SCIENTIST

I am currently a graduate student in physics at University of California Santa Cruz. I have a broad range of research interests in applied physics. While completing my undergraduate degree in physics at San Francisco State University, I studied holographic optical tweezers and exoplanet detection via radial velocity measurements. Since starting my graduate studies my attention has focused on the possibility of applying machine learning algorithms to a wide range of problems in quantum and classical physics.

Outside of research I enjoy outdoor activities like climbing, long-distance running and camping. I've visited 10 countries so far, including a year lived in Germany, and more to come! On lazier nights I play guitar, eat pizza and pray that the 49ers will make it to the Superbowl this year.



## FRANCISCO RODRIGUEZ-LERA COMPUTER SCIENTIST

I received my Ph.D. degree in intelligent systems for engineering in 2015 from the School of Industrial Engineering and Information Technology at University of León (Spain). Currently, I am working as a research associate in the AI Robolab, which belongs to the Computer Science and Communications Research Unit (CSC) at University of Luxembourg. Much of my work and research interest lies on four different topics associated with AI and Robotics: cognitive architectures motivational-oriented for robot control generating natural behaviors in autonomous robots; software development and DevOps for delivering solutions in research and business scenarios; application of AI and robots solutions for home-like environments and public spaces; and artificial neural networks systems applied to context-awareness in human-robot interaction environments.



## ANA MOSQUERA PLANETARY SCIENTIST

Ana M. Mosquera is a Scientific Computing Expert with a Ph.D. in Astrophysics. Born and raised in Montevideo, Uruguay, where she obtained her B.Sc. in Physics/Astronomy, she attended grad school at the University of Valencia, Spain, under the FP7 Marie Curie Research Training Program. After graduation she held a postdoctoral position in the Department of Astronomy at The Ohio State University, later joining the U. S. Naval Academy as a Visiting Assistant Research Professor in the Department of Physics. During this period she made pioneering contributions to the area of quasar structure using microlensing techniques. She later moved into Planetary Sciences and entrepreneurship, co-founding Aten Engineering Inc., where she has lead software initiatives to discover, follow-up and characterize Near Earth Asteroids, with the goals of increasing the safety of our planet, and enabling in-space resource extraction and utilization. She currently serves as an advisor to the company in different capacities.

# 02



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## LOCALIZATION: MERGING ORBITAL MAPS WITH SURFACE- PERSPECTIVE IMAGERY

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A significant challenge faced during the execution of lunar or planetary surface missions is that of localizing a perspective with respect to satellite imagery - something we on Earth take for granted in the age of GPS.

## SPACE RESOURCES 02 // MENTORS

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**AI MENTOR  
REDOUANE BOUMGHR**

[redouane.boumghar@desa.int](mailto:redouane.boumghar@desa.int)

Redouane Boumghar is Data Scientist at the Advanced Mission Concepts group at the European Space Operations Center. Redouane does research in Artificial Intelligence and Information Science and Machine Learning applied to space operations. Machine learning, predictive analytics, data visualization compose his everyday life. Driven by love and sharing, as an advocate of open culture, he spins in and off technologies.



**PLANETARY MENTOR  
J.L. GALACHE**

[yg279@cam.ac.uk](mailto:yg279@cam.ac.uk)

J.L. Galache, PhD, is an asteroid astronomer turned NewSpace entrepreneur. He has designed and directed asteroid data projects with NASA's Frontier Development Lab and Oracle. At the Minor Planet Center (Harvard-Smithsonian Center for Astrophysics), J.L. was Acting Deputy Director, where he helped keep the world safe from killer asteroids. He has discussed asteroids as an expert commentator in every type of media: Radio, TV, documentaries, newspapers and online publications. He is an advisor to Deep Space Industries.

## SPACE RESOURCES 01 // MENTORS

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### PLANETARY MENTOR **PHIL METZGER**

[philtill777@gmail.com](mailto:philtill777@gmail.com)

Dr. Philip Metzger is a planetary physicist who recently retired from NASA's Kennedy Space Center, where he co-founded the KSC Swamp Works. He now is now at the University of Central Florida -- but still a part of the Swamp Works team -- performing research related to solar system exploration: predicting how rocket exhaust interacts with extraterrestrial soil, investigating the mechanics of soil, characterizing lunar and martian soil simulants, modeling the migration of volatiles on airless bodies, etc. While at NASA he led the Agency's work in rocket blast effects for human-class missions.



### PLANETARY MENTOR **ALLISON ZUNIGA**

[allison.f.zuniga@nasa.gov](mailto:allison.f.zuniga@nasa.gov)

Dr. Allison Zuniga serves as the Project Development Manager for Cis-Lunar Space at the NASA Ames Space Portal Office. She has worked for NASA for over 25 years as an aerospace engineer and project manager. She has held positions at NASA Headquarters, NASA Goddard Space Flight Center, NASA Johnson Space Center and NASA Armstrong Flight Research Center. She holds a Bachelor of Science degree in Aerospace Engineering from Syracuse University; a Master of Science degree in Aerospace Engineering from USC; and a Doctor of Engineering degree in Aeronautics and Astronautics from Stanford University. She has publications in aerodynamics, space vehicle design, control system optimization, systems engineering, integrated vehicle health management and commercial space partnerships.



**PLANETARY MENTOR  
MARK SHIRLEY**  
**[mark.h.shirley@nasa.gov](mailto:mark.h.shirley@nasa.gov)**

Mark is a Mission Operations Engineer at NASA Ames Research Center. Previously Mark has also worked as a member of the operations and science team for LADEE, as a software lead for Lunar Crater Sensing and Observation Satellite, and as a Research Staff at NASA Ames. Before joining NASA, Mark was part of the research staff at Xerox. He received his PhD in Computer Science from Massachusetts Institute of Technology.



**PLANETARY MENTOR  
BRUCE PITTMAN**  
**[bpittman@earthlink.net](mailto:bpittman@earthlink.net)**

Bruce Pittman works at NASA as the Director of Flight Projects and Chief System Engineer in the NASA Space Portal and the Emerging Space Office at the NASA Ames Research Center. He is also the founder and president of Profit Engineering Technologies. Mr. Pittman supports programs ranging from suborbital human-tended research; orbital applications of the International Space Station and other orbiting commercial facilities; low cost, reliable access to space, reusable space infrastructure as well as cis-lunar commercialization. He has been involved in high technology project development, project management and system engineering in a variety of industries for over 30 years.

## SPACE RESOURCES 01 // MENTORS

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AI MENTOR  
**NAGIB HAKIM**  
[nagib.hakim@intel.com](mailto:nagib.hakim@intel.com)

Nagib Hakim is a Principal Engineer in the AI Product Group at Intel Corporation. He received his MS and Ph.D. degrees in electrical engineering from Columbia University in 1986 and 1992, respectively, focusing on neural network applications to signal processing and medical imaging. He joined Intel Corporation in 1992, where he conducted extensive development in the areas of semiconductor manufacturing technology and design, including statistical circuit modeling and optimization, reliability, and power/performance analysis. He extended these techniques to system-level modeling and post-silicon validation. He is currently focusing on AI solutions to various industrial problems. He has published more than 50 papers and holds one patent. He was a recipient of the SRC Outstanding Industry Liaison Award in 2012.

Mentor for both teams.



## SPACE RESOURCES 02 // MEET THE TEAM

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**ANDREW CHUNG**  
COMPUTER SCIENTIST

Andrew Chung is a computer vision and machine learning research engineer. Since completing his PhD. in computational astrophysics in 2016 he has worked on perception for autonomous cars at Hyundai Mobis, with a focus on deep neural networks. After the NASA Frontier Development Lab program he will embark on a new adventure at Audi Electronics Venture. Andrew's academic background spans Computer Science (BSc., University College London), Mathematical Physics (BSc., University of Edinburgh/Caltech), Astronomy (MS, University of Illinois at Urbana-Champaign), and Physics (PhD., Max Planck Institute for Astrophysics).

Previous research topics include real-time computer graphics, virtual environments, virtual machine infrastructure, automated stellar spectra classification, spaceborne monitoring of atmospheric methane, quasar detection, cosmological constraints from big bang nucleosynthesis, and the use of Lyman- $\alpha$  in studying models of galaxy formation and galactic outflows (PhD. thesis). Beyond work, Andrew also enjoys surfing, bouldering, snowboarding, photography, and generally having pun.



**PHILIPPE LUDVIG**  
COMPUTER SCIENTIST

Coming from the teeny tiny country of Luxembourg, I studied computer visualisation and computer sciences. After working in the film industry and with virtual reality, I moved onto computer vision for low performance computing platforms. Additionally, I also worked for the European Space Agency, where I was involved with Ground Data Systems for Science Missions, and studies into the remote operation of planetary rovers. Currently, I am doing my PhD research on Localisation and Mapping for a small Lunar rover. This is done in collaboration with ispace, which was one of the Google Lunar Xprize competition finalists.

When I'm not working on anything space-related, you'll usually find me behind a camera, either for photography or film. I am looking forward to meeting everyone and excited about collaborating together for the successful outcome of the different FDL projects.

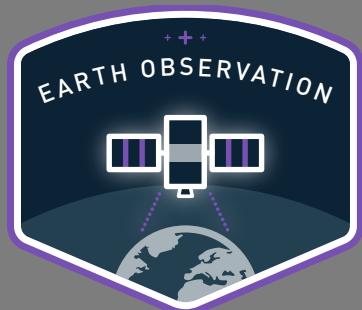
**BEN WU**  
**PLANETARY SCIENTIST**

Prior to the NASA FDL program, Ben Wu was a postdoctoral fellow in theoretical astrophysics at the National Astronomical Observatory of Japan (NAOJ). He develops and runs magnetohydrodynamics simulations on supercomputers in order to research the collapse of interstellar gas into stars. Using these multi-scale, multi-physics models, predictions can be made to compare with and better understand star formation activity observed throughout the universe. He completed his Ph.D. in Physics at the University of Florida and B.S. in Mathematics and Physics at Duke University.

He is also an avid proponent of space exploration, science outreach, and emerging technologies. When his head is not in the interstellar clouds, he can most likely be found on the rocks at a local climbing gym, in a hole-in-the-wall izakaya, or on Kerbin helping out with the Kerbal Space Program.

**ROSS POTTER**  
**PLANETARY SCIENTIST**

I am a planetary scientist- turned – data scientist. I have a PhD in planetary science from Imperial college London and have undertaken postdocs at the Lunar and Planetary Institute in Houston, TX and Brown University in Providence, RI. My research focus was numerical modelling of adterios impacts. I simulated and investigated the formation and structure of some of the largest craters in the Solar System, including South Pole – Aitken basin on the moon and Caloris basin on Mercury. I currently work as a data scientist for GTA, a travel company in London, using data analytics tools and machine learning to better understand client and destination search and booking behaviour.



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# A 'MISSION CONTROL' FOR PLANET EARTH

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The advent of spacecraft systems such as Sentinel 2 and Planet's Dove constellation allows us to - in theory - understand the changing nature of the Earth as never before. However the bottleneck remains the ability to quickly make sense of this new data availability, both in terms of refresh rates and heterogeneity, particularly when paired with ground data (such as mobile phone, drone and social media). How can these awesome new capabilities come together to provide a useful way of observing our entire planet dynamically? One notion is the concept of a 'Mission Control' for Planet Earth, where AI workflows automate the task of large scale multispectral data fusion and change detection.



## MENTORS

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**VERONIKA KOPACKOVA**  
EARTH SCIENTIST



**ATILIM GUNES BAYDIN**  
COMPUTER SCIENTIST



**PIOTR BILINSKI**  
COMPUTER SCIENTIST



**GUY SCHUMANN**  
EARTH SCIENTIST



**SYLVESTER  
KACZMAREK**  
COMPUTER SCIENTIST

## RESEARCHERS

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**TIM RUDNER**  
COMPUTER SCIENTIST



**JAKUB FIL**  
COMPUTER SCIENTIST



**MARC RUSSWURM**  
EARTH SCIENTIST



**RAMONA PELICH**  
EARTH SCIENTIST



**INDHU VARATHARAJAN**  
COMPUTER SCIENTIST



**BRADLEY GRAM-  
HANSEN**  
COMPUTER SCIENTIST



**DIMITRIOS MARMANIS**  
EARTH SCIENTIST



**FAIZA AZAM**  
EARTH SCIENTIST

# HOW FDL WORKS:

## THE POWER OF INTERDISCIPLINARY APPROACHES IN AI



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FDL's interdisciplinary format has demonstrated particular utility in applying the full spectrum of AI tools to problems that are both loosely defined (but have a large NASA data resource) and problems with a more tightly defined problem definition — which can be broken down and resolved by applying a 'full stack' of AI approaches. FDL teams have produced promising results with often sparse data sets by blending emerging unsupervised learning techniques, such as Generative Adversarial Networks (GANs), Variational Auto-Encoders (VAEs) and traditional machine learning tools like Bayesian Optimization.

The point of difference is the ability of FDL teams to be tailored to the challenge at hand — by choosing interdisciplinary teams of researchers, mentors and private sector advisors from leading institutions around the world who bring both a diverse understanding of the problem and solution space at the Phd and post-doc level. FDL also runs its challenges in parallel, deliberately creating an envelope of expertise around a subject area - encouraging cross-pollination, skills sharing and powerful competitive, but cooperative cultural dynamics that spur exemplary results.

Lastly, FDL's status as a public / private partnership allows researchers to freely access NASA data and access to principal investigators (PIs), while also benefit from state-of-the-art GPU compute resources, training and mentorship from the private sector - critical for the rapid iteration so important for driving progress.



# ACCELERATION METHODOLOGY

**01**

## START WITH LASER-FOCUSED PROBLEM DEFINITION

By starting with a tightly articulated goal, FDL contributors can more effectively search for relevancy - in other words, focus matters - especially as a team learns to work together.

**02**

## TEAMS OF INTERDISCIPLINARY EXPERTS

Breakthroughs invariably happen when domain specialties collide, or to use a visual metaphor, at the edges of the bell curve. Psychologists point to group think, attention blindness and other cognitive biases (such as the Asch conformity bias) as the reasons why seasoned experts often can't see what fresh eyes can.

**03**

## CO-OPEITION

Rather than working competitively on the same problem (without sharing resources), our FDL teams are tasked to work on related but adjacent challenges within a culture of co-operation and open discussion - building on each other's work in a generative way. The net result is a much broader set of skills - and fresh heads - applied to the challenges at hand.

## 04

### ENCOURAGE OBLIQUE DISCOVERY THROUGH RAPID ITERATION

Doing things, iterating, making mistakes and learning comprise the unspoken engine of invention. However, as Stephen Covey points out in his book, 'Where good ideas come from', chance favors the prepared mind. Where experience has immense benefit is the ability to see the value in a wrong turn or accidental ('oblique') discovery. Everything from Superglue to the Big Bang was discovered this way. Hence we are supporting our FDL teams with seasoned mentors and coaches

## 05

### ALLOW FOR INDIRECT INSPIRATION

Indirect inspiration is the ability of our brains to see a pattern in one place and apply it in a different context to discover something completely new. This is sometimes called 'analogous inspiration' and is the mechanism behind methodologies such as biomimicry. At FDL we are building this into the 8 week syllabus by inviting guests and speakers from multiple industries, as well as organizing field trips and other opportunities for inspiration.

## 06

### PLAN FOR COLLECTIVE RECOGNITION

As a team makes its journey of discovery, it self-educates, creating a deeper understanding of a problem. This mature understanding allows collective recognition when a solution presents itself. Invariably true breakthroughs take this form - rather than a light bulb moment, or lone act of genius, the team arrives at a powerful piece of thinking in the form of a 'slow hunch'.

**01****02****03**

# INNOVATION AWARDS

**01**

## MOST DRAMATIC PIVOT

Pivoting is an action taken when new opportunities arise unexpectedly. Sometimes this means starting completely from scratch after much commitment is put into one idea. The "Most Dramatic Pivot" award represents these changes in direction, at times unwanted but certainly necessary.

**02**

## DATA SAMARITAN

The Award for Data Samaritan can be comparable to that of the sportsmanship award. It highlights the necessity for a key trait to be manifested in order to contribute to the greater good of science and research. It's the ability one (or the group) holds to put aside their immediate goals and help those in need of it.

**04****05****03**

## **UNEXPECTED DISCOVERY**

Just like dirty dishes helped the discovery of Penicillin, and melting chocolate bars triggered the creation of the microwave, the “Unexpected Discovery” Award represents that ability to stumble upon a breakthrough, as Plato once said: “Science is nothing but perception”.

**04**

## **HEROIC COMEBACK**

“Heroic Comeback” is an acknowledgement that when discovering something genuinely new, you have to first fail. But that’s only one half of the story. Simply failing isn’t enough. Getting back up, learning, evolving and trying again is how legends are made.

**05**

## **COLLABORATIVE SPIRIT**

The Collaborative Spirit Award is the representation of FDL’s beating heart: interdisciplinary research. It supports the idea that to achieve great things, two (or 20) minds are better than one, and the exchange of knowledge is key.

## WEEK 1 // BOOTCAMP

### WEEK 1 // BOOTCAMP

25th June Mon	<b>ASTROBIOLOGY DAY</b> 26th June   Tues	<b>SPACE WEATHER DAY</b> 27th June   Weds	<b>EXOPLANET DAY</b> 28th June   Thurs	<b>SPACE RESOURCE DAY</b> 29th June   Fri	30th June Sat
09:00	<b>WELCOME</b> @ NVIDIA	<b>WELCOME</b> @ NVIDIA	<b>WELCOME</b> @ NVIDIA	<b>WELCOME</b> @ NVIDIA	<b>WELCOME</b> @ NVIDIA
10:00	<b>REVIEW OF 8 WEEKS</b> <b>RESEARCHERS</b> <b>CHECK-IN</b> @ SETI INSTITUTE	<b>INTRO TO ASTRO-</b> <b>BIOLOGY</b> @ NVIDIA	<b>INTRO TO SPACE</b> <b>WEATHER</b> @ NVIDIA	<b>INTRO TO EXOPLANETS</b> @ NVIDIA	<b>INTRO TO SPACE</b> <b>RESOURCES</b> @ NVIDIA
11:00	<b>AI SPEAKER</b> @ NVIDIA	<b>AI SPEAKER</b> @ NVIDIA	<b>AI SPEAKER</b> @ NVIDIA	<b>AI SPEAKER</b> @ NVIDIA	<b>AI SPEAKER</b> @ NVIDIA
12:00	<b>LUNCH BREAK</b>	<b>LUNCH BREAK</b>	<b>LUNCH BREAK</b>	<b>LUNCH BREAK</b>	<b>LUNCH BREAK</b>
13:00					
14:00					
15:00	<b>MEET THE TEAMS</b>	<b>BREAKOUT GROUPS</b> @ NVIDIA	<b>BREAKOUT GROUPS</b> @ NVIDIA	<b>BREAKOUT GROUPS</b> @ NVIDIA	<b>BREAKOUT GROUPS</b> @ NVIDIA
16:00	<b>LIGHTING TALKS</b> @ SETI INSTITUTE				
17:00					
18:00		<b>WELCOME</b> <b>RECEPTION</b>			<b>CLOSE OUT</b> @ SPACE PORTAL
19:00					
20:00					 <b>NVIDIA</b>
21:00					 <b>SPACE PORTAL</b>
					 <b>Google Cloud</b>
					 <b>AI</b>
					<b>AI TOOLS TRAINING</b>
					<b>AI TOOLS TRAINING</b>

## WEEK 2 // BIG IDEAS WEEK

2nd July Mon	THINK BIG DAY 1 3rd July   Tues	09:00 <b>GROUP MEETING</b> @ SETI INSTITUTE	10:00 <b>ANNOUNCEMENTS</b> @ SETI INSTITUTE	11:00 <b>TEAM MEETINGS</b> @ SETI INSTITUTE	12:00 LUNCH BREAK	13:00 LUNCH BREAK	14:00 DEFINE & PLAN WITH MENTORS @ SETI INSTITUTE	15:00 DEFINE & PLAN WITH MENTORS @ SETI INSTITUTE	16:00 DEFINE & PLAN WITH MENTORS @ SETI INSTITUTE	17:00 HOLIDAY	
4th July Wed	THINK BIG DAY 2 5th July   Thurs	09:00 <b>ANNOUNCEMENTS</b> @ SETI INSTITUTE	10:00 <b>DEFINE &amp; PLAN</b> WITH MENTORS @ SETI INSTITUTE	11:00 LUNCH BREAK	12:00 LUNCH BREAK	13:00 LUNCH BREAK	14:00 DEFINE & PLAN WITH MENTORS @ SETI INSTITUTE	15:00 DEFINE & PLAN WITH MENTORS @ SETI INSTITUTE	16:00 DEFINE & PLAN WITH MENTORS @ SETI INSTITUTE	17:00 INTERIM CONCEPT REVIEW @ SETI INSTITUTE	
5th July Fri	6th July Sat	09:00 <b>ANNOUNCEMENTS</b> @ SETI INSTITUTE	10:00 <b>DEFINE &amp; PLAN</b> WITH MENTORS @ SETI INSTITUTE	11:00 LUNCH BREAK	12:00 LUNCH BREAK	13:00 LUNCH BREAK	14:00 DEFINE & PLAN WITH MENTORS @ SETI INSTITUTE	15:00 DEFINE & PLAN WITH MENTORS @ SETI INSTITUTE	16:00 DEFINE & PLAN WITH MENTORS @ SETI INSTITUTE	17:00 INTERIM CONCEPT REVIEW @ SETI INSTITUTE	
6th July Fri	7th July Sat	09:00 <b>ANNOUNCEMENTS</b> @ SETI INSTITUTE	10:00 <b>DEFINE &amp; PLAN</b> WITH MENTORS @ SETI INSTITUTE	11:00 LUNCH BREAK	12:00 LUNCH BREAK	13:00 LUNCH BREAK	14:00 DEFINE & PLAN WITH MENTORS @ SETI INSTITUTE	15:00 DEFINE & PLAN WITH MENTORS @ SETI INSTITUTE	16:00 DEFINE & PLAN WITH MENTORS @ SETI INSTITUTE	17:00 INTERIM CONCEPT REVIEW @ SETI INSTITUTE	

## WEEK 3 // CONCEPT DEFINITION WEEK

## WEEK 4 // PROTOTYPE WEEK

16th July Mon	17th July Tues	18th July Weds	19th July Thurs	20th July Fri	21st July Sat			
09:00 <b>ANNOUNCEMENTS</b> @ SETI INSTITUTE	10:00 <b>TEAM MEETINGS</b> @ SETI INSTITUTE	11:00 <b>DEVELOP WITH MENTORS</b> @ SETI INSTITUTE	12:00 <b>LUNCH BREAK</b>	13:00 <b>DEVELOP WITH MENTORS</b> @ SETI INSTITUTE	14:00 <b>DEVELOP WITH MENTORS</b> @ SETI INSTITUTE	15:00 <b>DEVELOP WITH MENTORS</b> @ SETI INSTITUTE	16:00 <b>EVENING SPEAKER</b> @ SETI INSTITUTE	17:00 <b>INTERNAL CONCEPT REVIEW</b> @ SETI INSTITUTE
18:00	19:00	20:00	21:00					

## WEEK 4 // PROTOTYPE WEEK

## WEEK 5 // PROTOTYPE WEEK

## WEEK 6 // DRAFT WEEK

30th July Mon	31st July Tues	1st August Weds	2nd August Thurs	3rd August Fri	4th August Sat		
09:00 <b>BREAKFAST SPEAKER</b> @ SETI INSTITUTE	ANNOUNCEMENTS @ SETI INSTITUTE	ANNOUNCEMENTS @ SETI INSTITUTE	TEST AND ITERATE @ SETI INSTITUTE	LUNCH BREAK	MILESTONE REVIEW @ SETI INSTITUTE	LUNCH BREAK	
10:00 <b>ANNOUNCEMENTS</b> @ SETI INSTITUTE	TEAM MEETINGS @ SETI INSTITUTE	TEST AND ITERATE @ SETI INSTITUTE	TEST AND ITERATE @ SETI INSTITUTE	LUNCH BREAK	TEST AND ITERATE @ SETI INSTITUTE	TEST AND ITERATE @ SETI INSTITUTE	
11:00 <b>TEAM MEETINGS</b> @ SETI INSTITUTE					EVENING SPEAKER @ SETI INSTITUTE		
12:00 LUNCH BREAK							
13:00							
14:00							
15:00 TEST AND ITERATE @ SETI INSTITUTE							
16:00							
17:00							
18:00							
19:00							
20:00							
21:00							

## WEEK 6 // DRAFT WEEK

## WEEK 7 // DRAFT WEEK

### WEEK 7 // DRAFT WEEK

30th July Mon	31st July Tues	1st August Weds	2nd August Thurs	3rd August Fri	4th August Sat
09:00 <b>BREAKFAST SPEAKER</b> @ SETI INSTITUTE	ANNOUNCEMENTS @ SETI INSTITUTE	ANNOUNCEMENTS @ SETI INSTITUTE	DRAFT WITH MENTORS @ SETI INSTITUTE	DRAFT WITH MENTORS @ SETI INSTITUTE	
10:00 <b>ANNOUNCEMENTS</b> @ SETI INSTITUTE					
11:00 <b>TEAM MEETINGS</b> @ SETI INSTITUTE					
12:00 <b>LUNCH BREAK</b>			<b>LUNCH BREAK</b>	<b>LUNCH BREAK</b>	
13:00					
14:00					
15:00 <b>DRAFT WITH MENTORS</b> @ SETI INSTITUTE			DRAFT WITH MENTORS @ SETI INSTITUTE	DRAFT WITH MENTORS @ SETI INSTITUTE	
16:00					
17:00					
18:00					
19:00					
20:00					
21:00					

## WEEK 8 // DELIVER WEEK

13th August Mon	14th August Tues	15th August Weds	16th August Thurs	17th August Fri	18th August Sat
09:00 <b>TEAM MEETINGS</b> @ SETI INSTITUTE	10:00 <b>ANNOUNCEMENTS</b> @ SETI INSTITUTE	11:00 <b>PEER REVIEW ALL TEAMS</b> @ SETI INSTITUTE	12:00 <b>LUNCH BREAK</b>	13:00 <b>PRESENTATION PREP</b> @ SETI INSTITUTE	
10:00 <b>ANNOUNCEMENTS</b> @ SETI INSTITUTE	11:00 <b>TEAM MEETINGS</b> @ SETI INSTITUTE	12:00 <b>LUNCH BREAK</b>	13:00 <b>FINAL PRESENTATIONS</b> @ INTEL	14:00 <b>DEBRIEF</b> @ SETI INSTITUTE	
11:00 <b>TEAM MEETINGS</b> @ SETI INSTITUTE	12:00 <b>LUNCH BREAK</b>	13:00 <b>PRESENTATION PREP</b> @ SETI INSTITUTE	14:00 <b>DELIVER WITH MENTORS</b> @ SETI INSTITUTE	15:00 <b>DELIVER WITH MENTORS</b> @ SETI INSTITUTE	
12:00 <b>LUNCH BREAK</b>	13:00 <b>PRESENTATION PREP</b> @ SETI INSTITUTE	14:00 <b>DELIVER WITH MENTORS</b> @ SETI INSTITUTE	15:00 <b>DELIVER WITH MENTORS</b> @ SETI INSTITUTE	16:00 <b>DELIVER WITH MENTORS</b> @ SETI INSTITUTE	
			17:00	18:00	19:00
				20:00	21:00

# LODGING

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## HOME AWAY FROM HOME

Participants will be hosted at NASA Ames, Moffett Field for the duration of the Frontier Development Lab.

## CHECK IN:

NASA Ames, Building 19  
Moffett Field, CA 94034

During the course of the program, you will live on-site at the NASA Ames Lodge Exchange.

NASA offers only dormitory accommodations, with each room providing double occupancy. FDL participants will be paired-up and assigned rooms upon check-in.

Each room is of good size and has two twin size beds, a microwave, full size refrigerator, basic bathroom facility, and internet access.

Toiletries and items such as hair dryers and irons are not provided in the rooms.

## NASA AMES LODGE MAIL ADDRESS

NASA Ames Lodge at Moffett Field  
PO Box 17, M/S 19-1  
Moffett Field, CA 94035

## FRONT DESK

(650) 603-7100 or (650) 603-7101

## SETI INSTITUTE: FDL HQ

SETI Institute,  
189 Bernardo Avenue, Suite 200  
Mountain View, CA 94043

## NASA AMES ON-SITE RESTAURANTS

### Space Bar (Building 3)

Saturday - Sunday: CLOSED

Monday - Friday: 11:00am - 7:00pm

### The Mega Bites Cafe (Building 235)

Saturday - Sunday: CLOSED

Monday - Friday: 6:00am - 2:00pm

## SWIM CENTER

### The Swim Center

(650) 603-8025

Monday - Friday only

10:00am - 1:00pm, 3:00pm - 6:00pm

Daily fee for non-members or guests:  
\$5.00

Westcoat and corner of Bailey Road  
Building #109

## TRANSPORT

### Caltrain | [www.caltrain.com](http://www.caltrain.com)

(good for visiting  
San Francisco or San Jose)

### VTA | [www.vta.org](http://www.vta.org)

(Santa Clara Valley  
Transportation Authority)  
Bus 81 at stop on North Akron and Mc  
Cord. Every 30 min Monday - Friday, and  
every 60 min on Saturdays

## LAUNDRY

The laundry facility is located in building 547B, within walking distance from the NASA Ames Lodge.

- Washing machine: \$1.50
- Drying machine: \$0.50
- The machines only accept quarters (25¢ coins).

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## NASA AMES RESEARCH PARK



## NASA AMES LODGE CHECK-IN



## ENTRANCE TO THE SETI INSTITUTE



# OUR CULTURE AND WORKING PRACTICES

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FDL is a professional (rather than academic) work setting. We expect all our team members to be physically present and intellectually engaged for the full eight weeks.

We also expect our researchers and mentors to respect their team mates, mentors and guest reviewers and speakers by arriving to sessions promptly and refraining from the temptations of social media, or “multi-tasking” with your phone or laptop, unless it is related to the FDL program.

We rely on everyone at FDL to foster a respectful and creative work environment. We ask everyone to be scientifically and academically enquiring and encourage (and expect) lively debate. But, we also insist on collegial attitudes and mutual respect for differing opinions and ways of working through challenging problems (e.g. making sure everyone on the team gets to share their opinions, not just the team mates with the loudest voice!)

We do not tolerate bullying, aggressive behavior or prejudice of any kind. Inappropriate conduct will result in us asking you to leave the program and withdrawal of all access, in kind and financial support. If you experience or witness any behavior that causes concern please report it confidentially to a member of the FDL facilitation team.

## (SOLAR)

July 5, 2017

Irradiance  
Radio burst  
Cosmic ray flux  
Solar wind  
Mean magnetic field (solar)  
geomagnetic

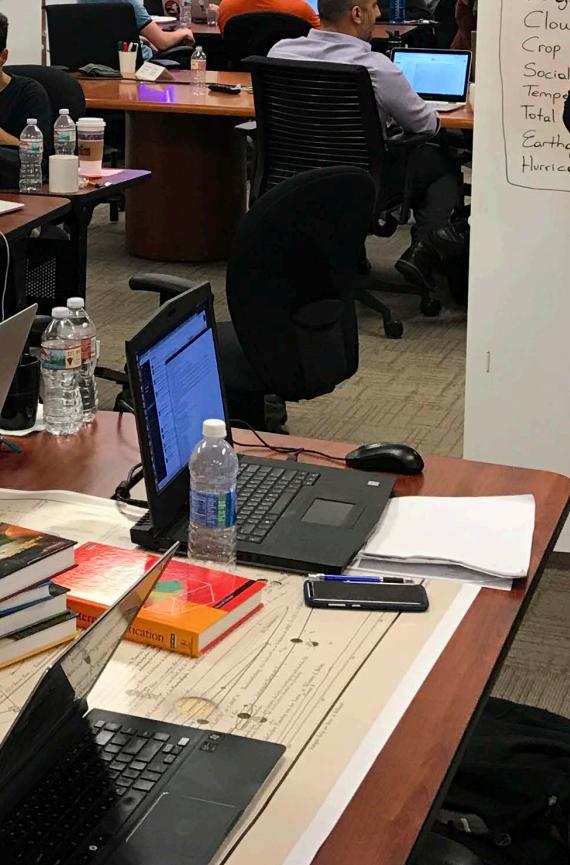
→ Already timeseries

## Terrestrial

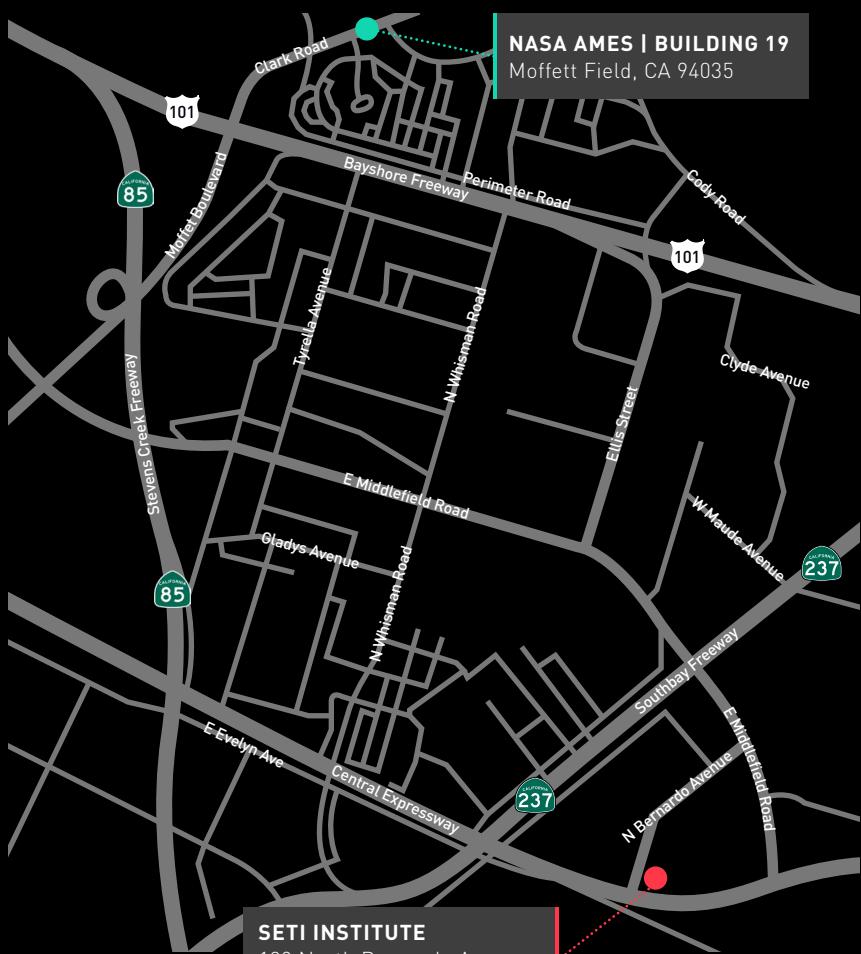
Lightning  
Cloud  
Crop  
Social  
Tempo  
Total  
Earthquakes  
Hurricanes +

Correlate ?

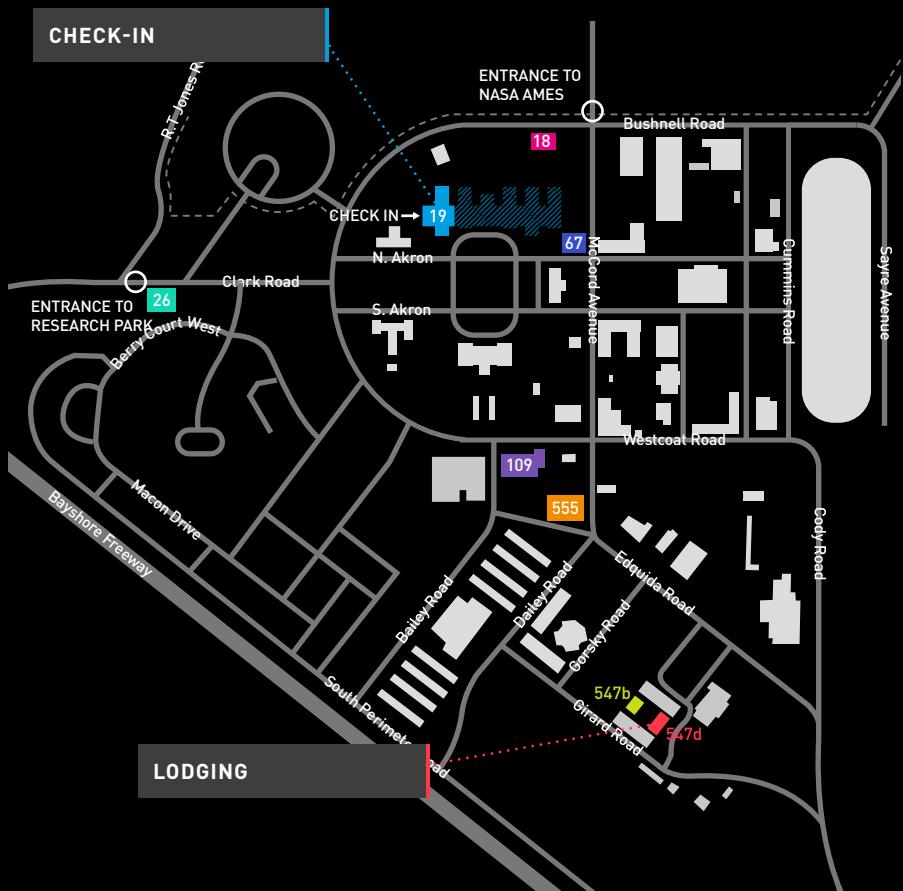
Time Data



# GETTING TO SETI INSTITUTE



# NASA AMES MAP



## KEY

- Bldg. 26**  
Main Gate / Badging
- Bldg. 19**  
NASA Lodge Registration

- Bldg. 547D**  
NASA Lodge rooms
- Bldg. 555**  
NASA Space Portal
- Bldg. 547B**  
Laundry Facility

- Bldg. 109**  
Swim Center
- Bldg. 67**  
USPS
- Bldg. 18**  
Breakthrough Initiative



AI RESEARCH FOR  
SPACE EXPLORATION  
AND ALL HUMANKIND

# 2018 RESEARCH PRESENTATIONS EVENT

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Meet with leaders in AI and Space Exploration.

**August 16th, 2018, Silicon Valley.  
1 pm onwards.**

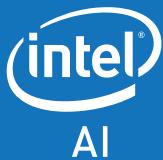
Tickets: [bit.ly/fdlevent2018](https://bit.ly/fdlevent2018)



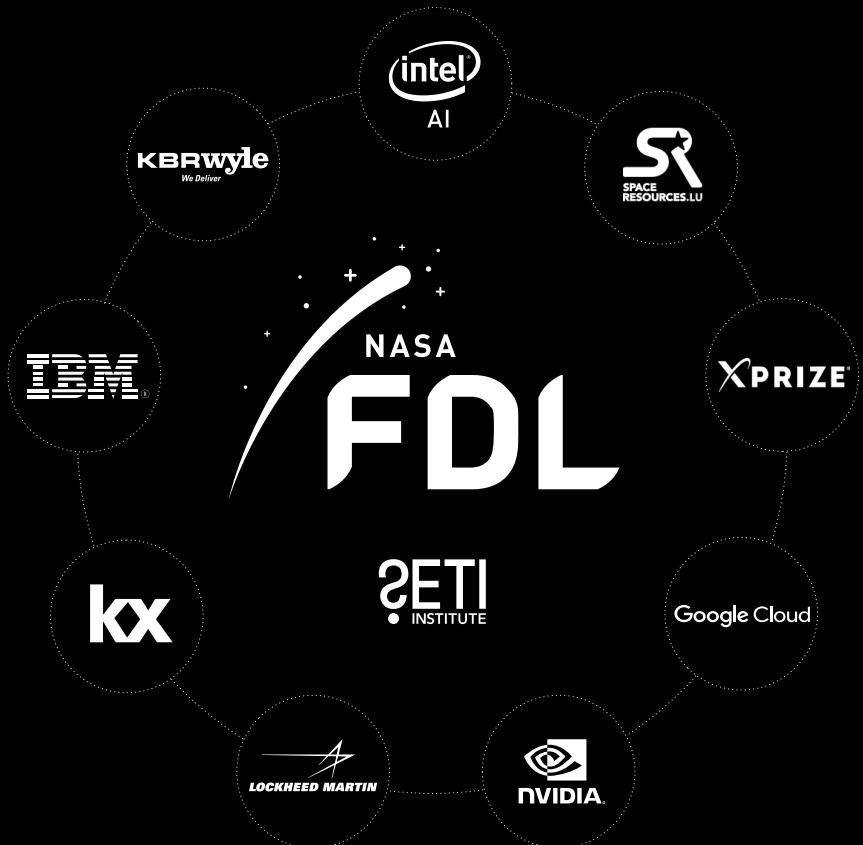
explainables  
SCIENCE COMMUNICATION

Presentation support by **The Explainables**.

Thanks to the team at Intel AI.



FDL 2018 Research Presentations Event  
hosted by Intel at the **Intel Santa Clara**  
**Auditorium, Silicon Valley**



#### NASA POINT OF CONTACT

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