



MISSION CONTROL

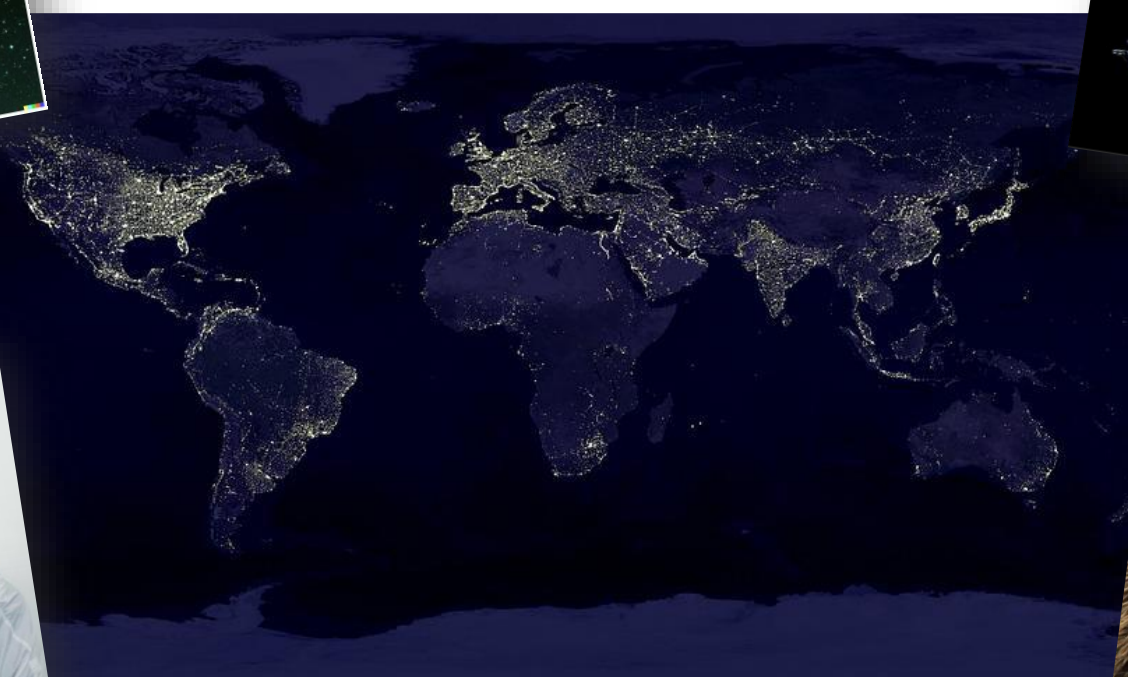


A Deep Learning Framework for Planetary Exploration Data and Model Management

A. J. Macdonald*, A. Budhkar, B. Bonham-Carter, E. Smal, M. Cross, K. Raimalwala, & M. Faragalli
macdonald@missioncontrolspaceservices.com

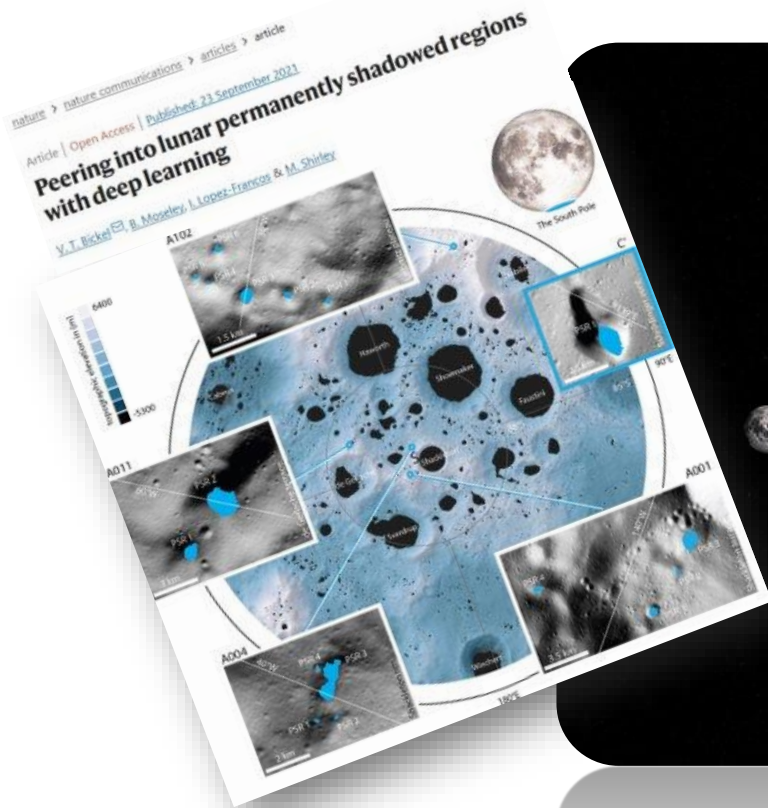
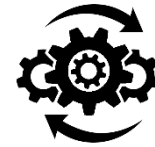
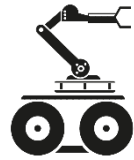
PSIDA
Villanueva de la Cañada, Spain
June 21-23, 2022

Deep Learning on and above Earth



Deep Learning for Deep Space

Emerging need for more complex space operations



Software for Earth, Moon and Mars

Mission Control innovates to make advanced software viable for use in space.

Founded in 2015

HQ in Ottawa, Canada

Competencies in space, robotics, software, science, and operations

Moonyard

Rover and robotic arm test facility
Small T-Vac

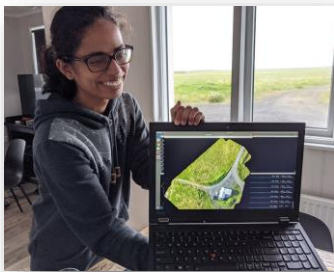
Confirmed Mission Contributions

2022 : Rover-lander radio shipped for a lunar mission

2022 : AI demo on ESA Ops-Sat

2023 : AI terrain classifier demo on lunar surface

2023 : Operations software to support a lunar rover mission

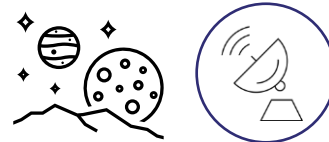


Mission Control Software

Operate Your Payload From Anywhere

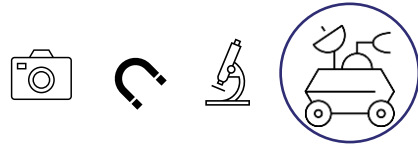
Connect to Spacecraft

Seamless transition from testing to flight



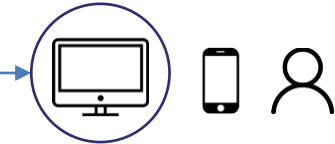
Robotic Systems and Payloads

Rapid prototyping and operations testing



Secure web-based interfaces

Robotics and payload operations

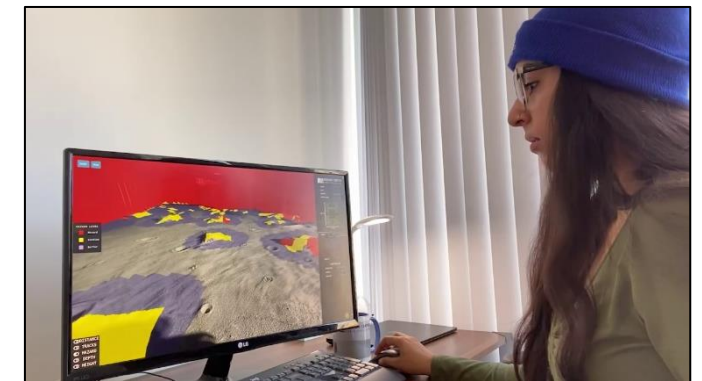


Mission Control Software

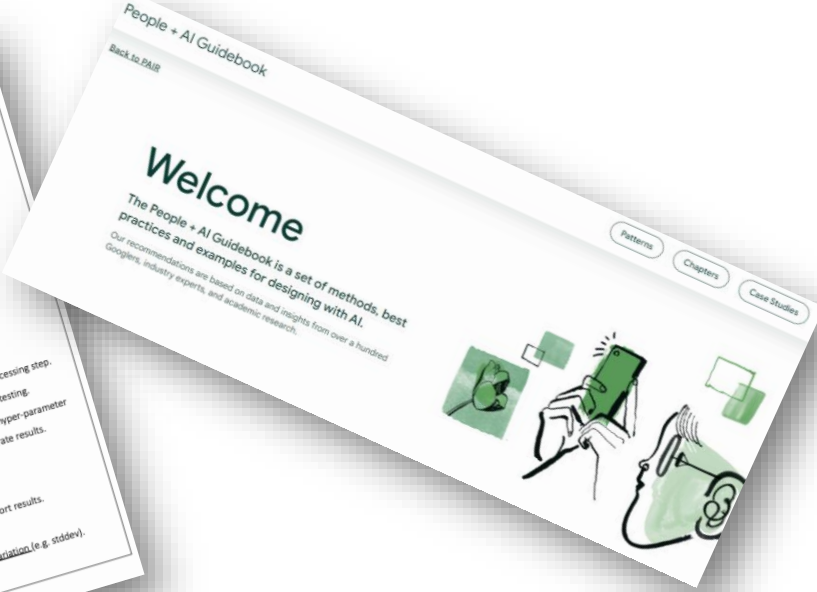
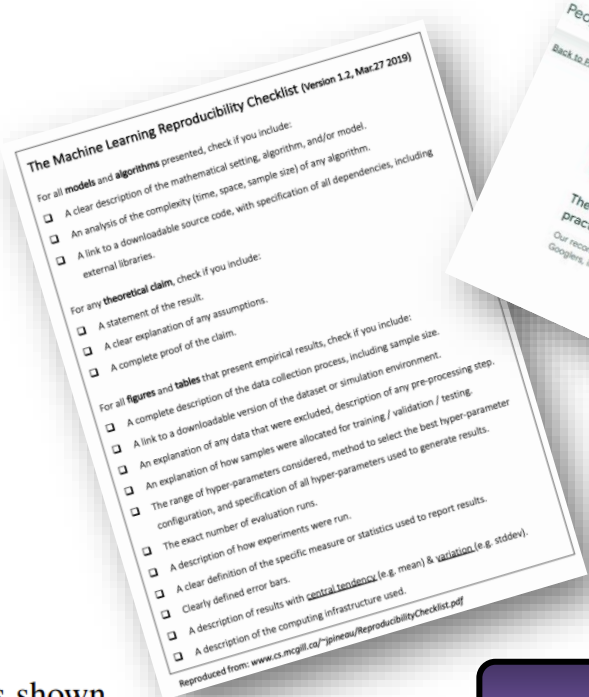
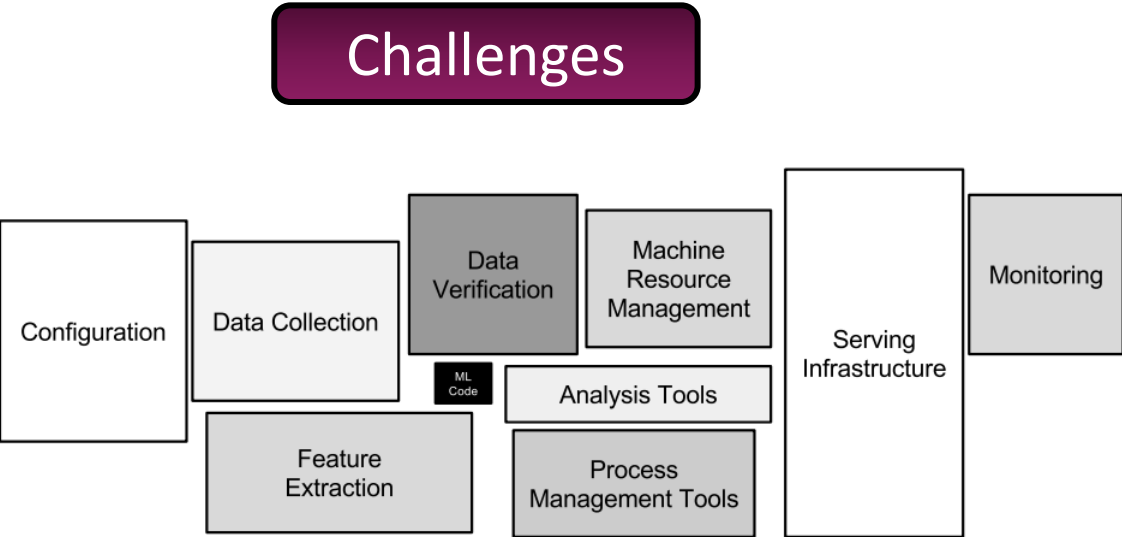
cloud-based platform

Local deployments for scenarios without internet

Developer-friendly SDK for easier integration



Building Robust Deep Learning Pipelines



Tools

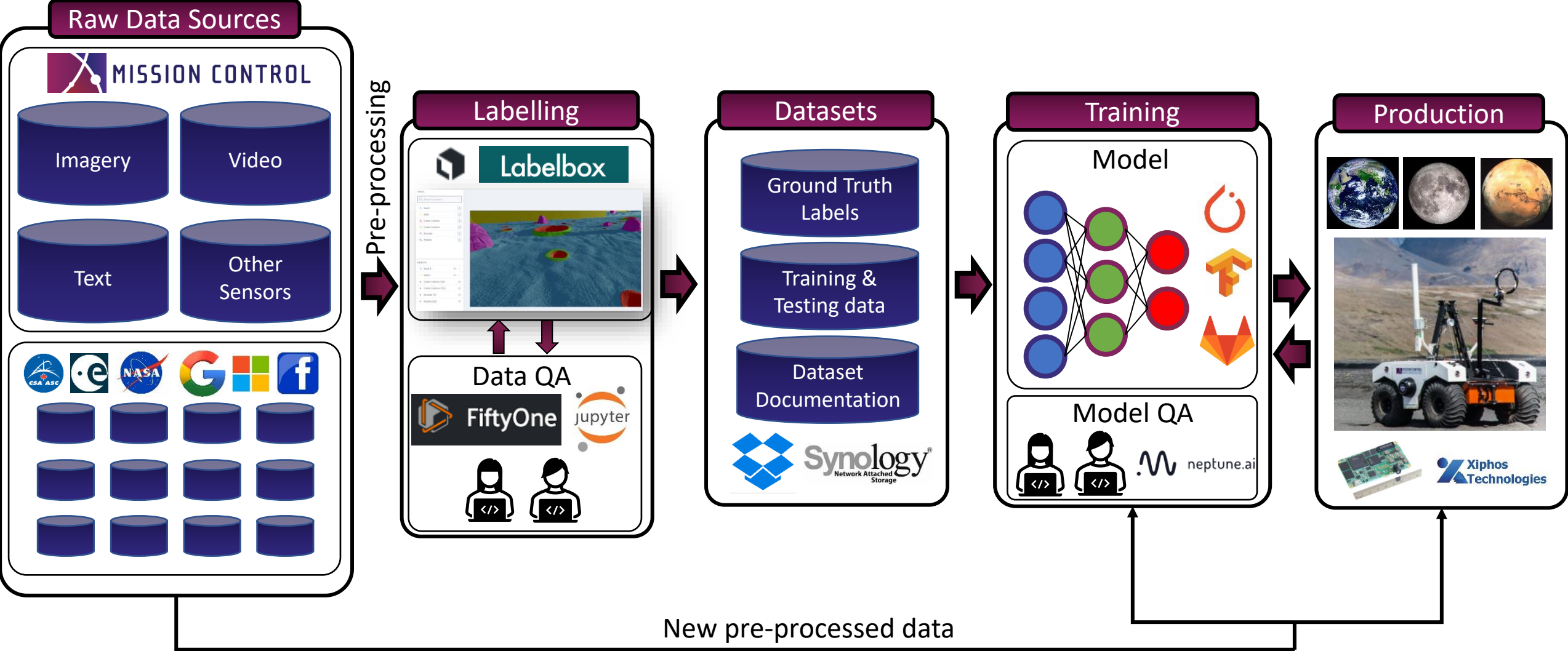
[Hidden Technical Debt in Machine Learning Systems \(neurips.cc\)](https://neurips.cc)

[Machine Learning: The High Interest Credit Card of Technical Debt – Google Research](#)

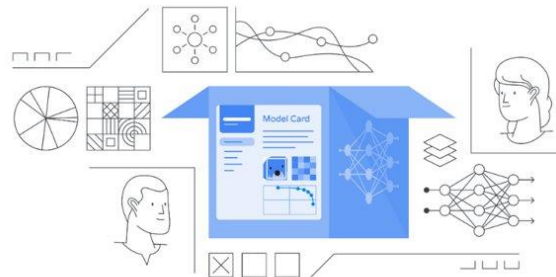
[ReproducibilityChecklist-v2.0 \(mcgill.ca\)](https://mcgill.ca)

[People + AI Research - Welcome \(pair.withgoogle.com\)](https://pair.withgoogle.com)

Mission Control Deep Learning Pipeline



Accessibility starts with Documentation



The value of a shared understanding of AI models

[Model Cards for Model Reporting \(arxiv.org\)](https://arxiv.org/abs/2206.01541)

[Google Cloud Model Cards](https://cloud.google.com/modelcard/)



Model Description
Intended Use
Metrics
Data
Recommendations
Ethical Considerations

Metrics

$$\text{Accuracy} = \frac{TP}{TP + FP}$$

$$\text{Mean IoU} = \frac{TP}{TP + FP + FN}$$



ASAS-CRATERS - Terrain Model

Autonomous Soil Assessment System Contextualizing Rocks, Anomalies and Terrains in Exploratory Robotic Science

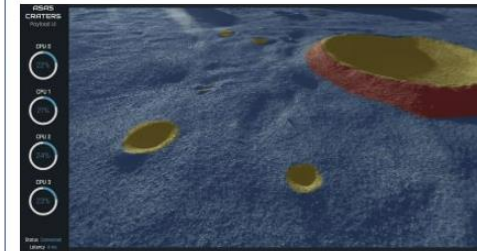
Model Type: Semantic Segmentation Convolutional Neural Net

Developed by: Mission Control Space Services

Model date: 2021 | Model version: 3.0?

Documentation: MCSS.1674 Final Concept Study Report, MCSS.1932 Embedded Test Report

Repository: - | License: -



Intended Use

- Segmenting terrain types commonly found in robotic planetary exploration
- Helping users identify non-geometric hazards and areas of interest to aid in navigation and increase scientific returns
- For use on the space segment or ground segment

Data

- Dataset classes are not balanced



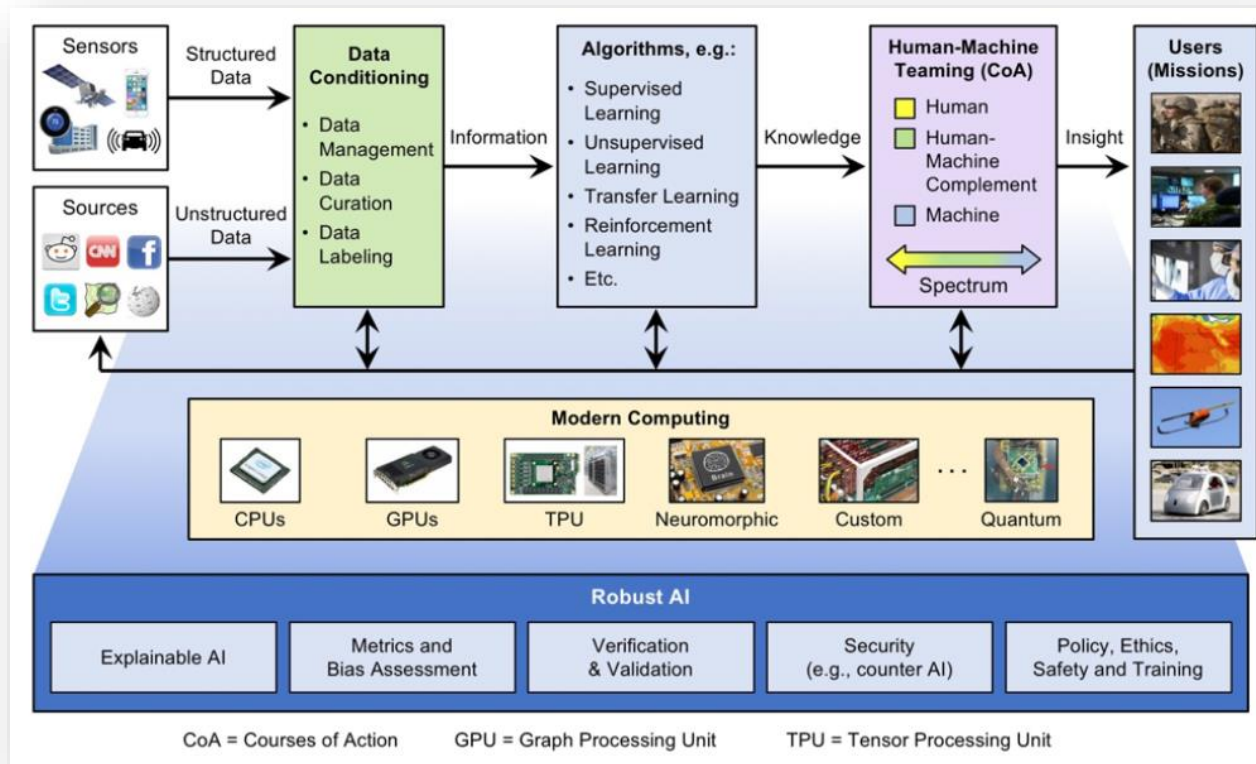
Recommendations

- ASAS-CRATERS underlying model is based off state-of-the-art segmentation research, as model backbones evolve it can be updated
- ASAS-CRATERS is not suitable for use on earth in areas with vegetation, water, or urban structures

Ethical Considerations

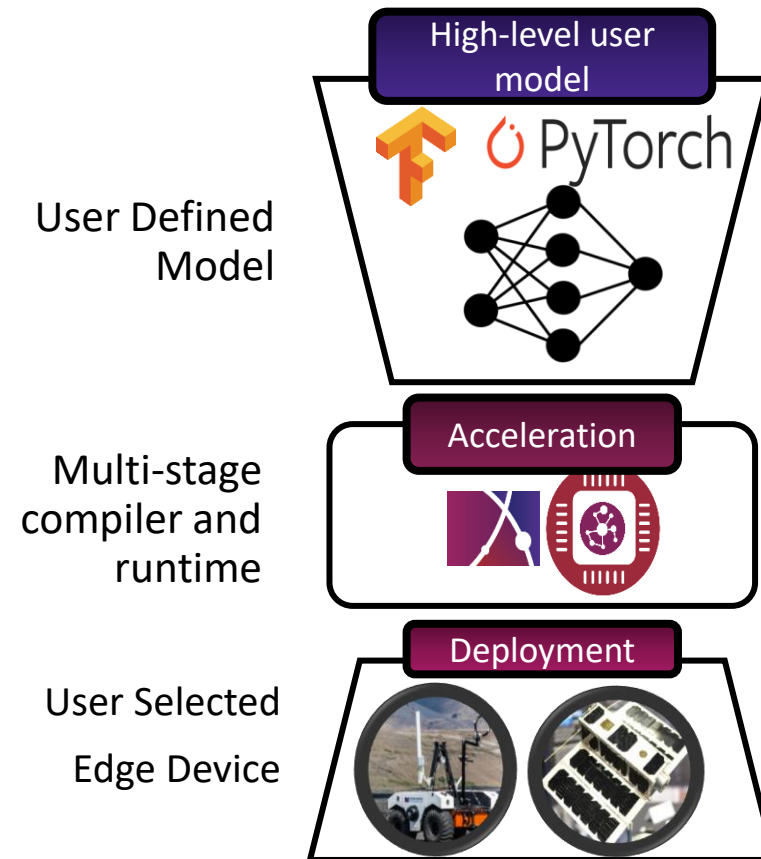
- No possible identification of personal or private information
- Labelling of training data performed through a paid professional vendor
- Class labels assigned in consultation with experts in the field (i.e., planetary geologists)

Addressing Pain Points in Deployment



[Survey and Benchmarking of Machine Learning Accelerators](#)

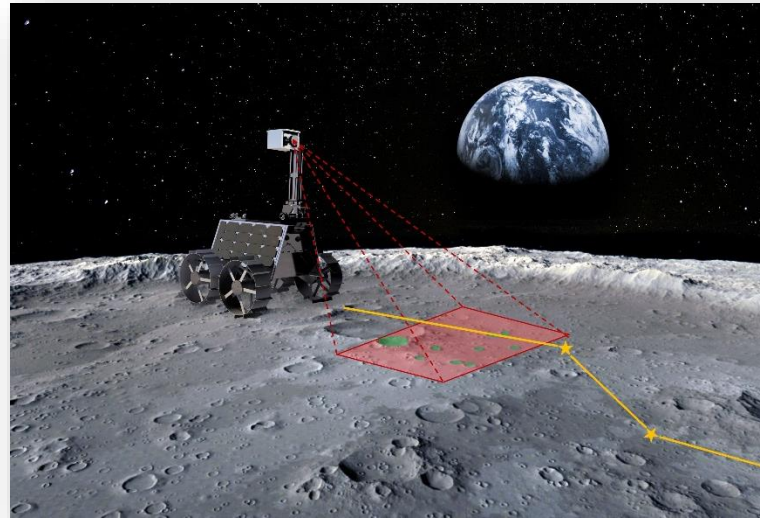
[Towards the Use of Artificial Intelligence on the Edge in Space Systems: Challenges and Opportunities](#)



Deep Learning in Flight



Emirates Lunar Mission
Segmentation Network for
Terrain Classification

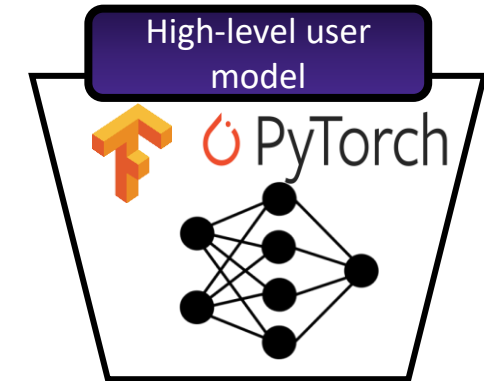


OPS-SAT

SmartCam Image
Classification for Satellite
Earth Observation



User Defined
Model



Multi-stage
compiler and
runtime



User Selected
Edge Device



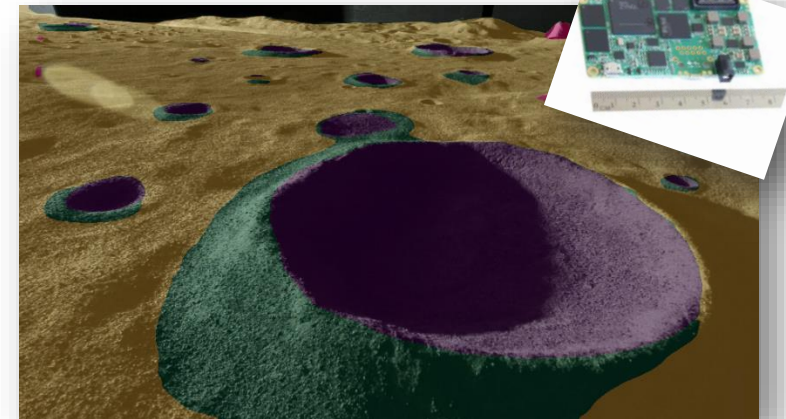
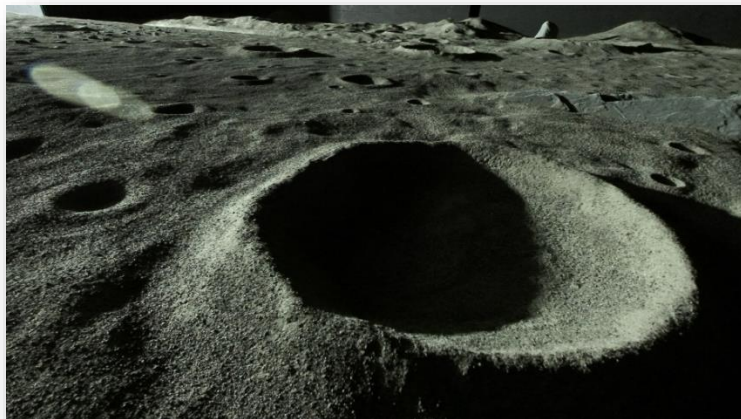
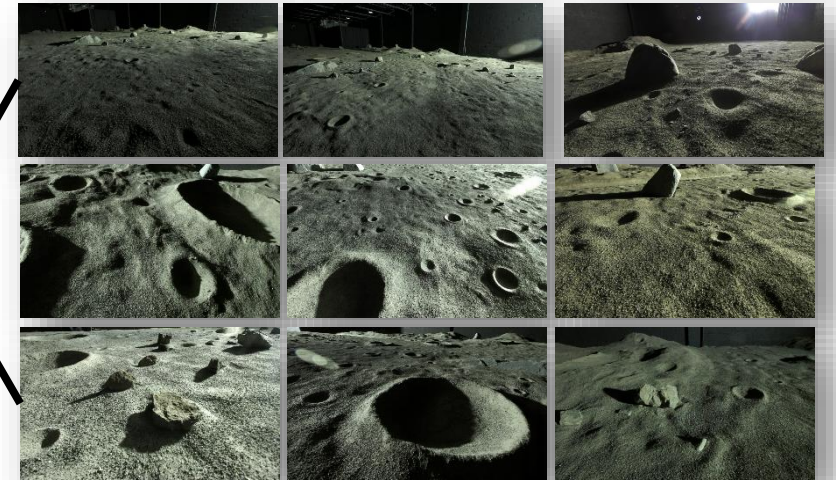
Lunar Surface AI Demonstration



Emirates Lunar Mission
Segmentation Network for
Terrain Classification



Moonyard training images



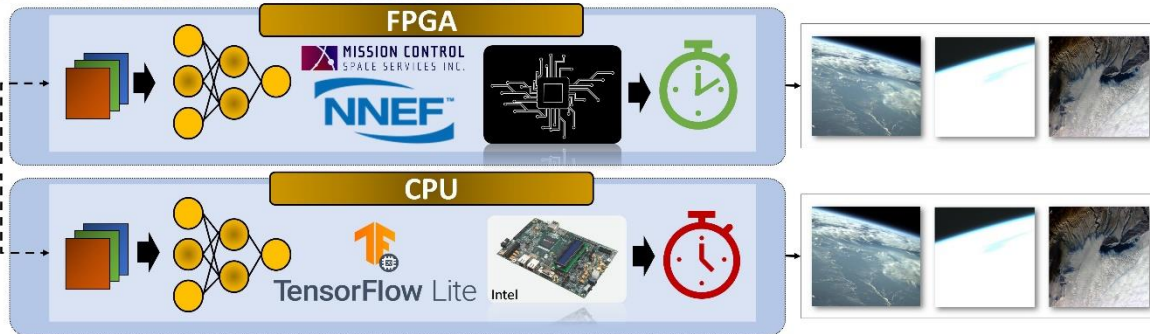
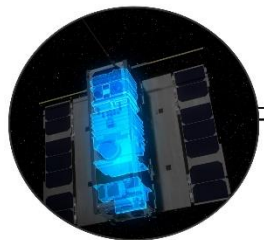
Acceleration on ESA OPS-SAT



European Space Agency



A Comparative Study of High-Level and Low-Level Implementations of Deep Learning Models for Spacecraft



[ESA - The Discovery Campaign on OPS-SAT experiments](#)



OPS-SAT SmartCam
i will neural network your earthies

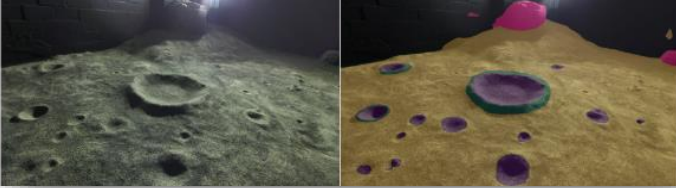
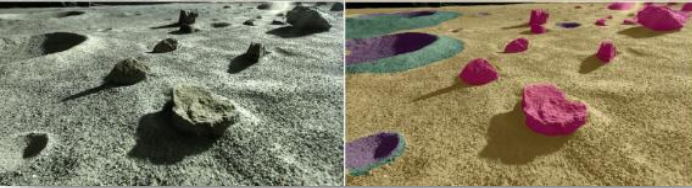


OPS-SAT
SmartCam Image Classification for Satellite Earth Observation

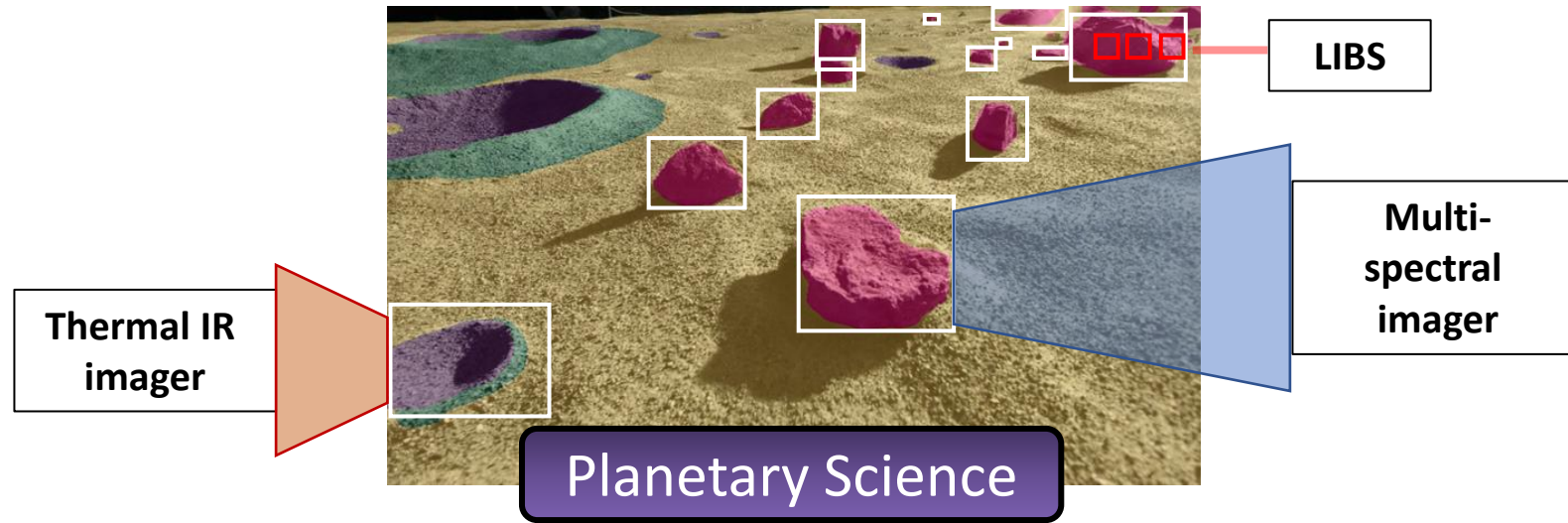
Distributed Deep Learning with ESA FRIENDS



[Open Space Innovation Platform - OSIP - Campaign: Cognitive Cloud Computing in Space \(esa.int\)](https://www.esa.int/OSIP)

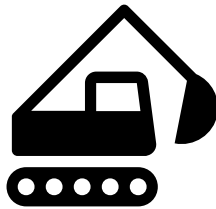


Where do we go from here?



Where can we take inspiration from?

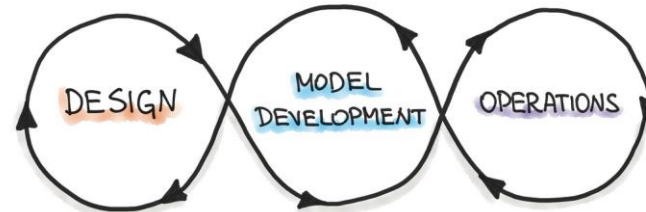
Mission Critical AI Applications



Fundamental AI Research

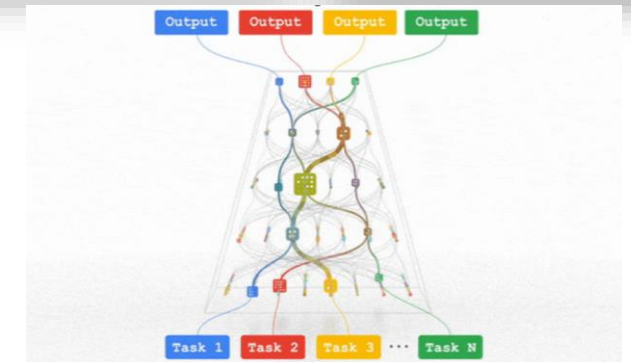
Symbolic AI		Deep Learning	
Input: highly structured		Input: takes raw inputs	
Function: highly structured		Function: weakly structured	
Interpretability	5 brains	Interpretability	1 brain
Data Efficiency	5 brains	Data Efficiency	1 brain
Transfer	3 brains	Transfer	1 brain
Universality	1 brain	Universality	5 brains

AI Operations



- DESIGN**
 - Requirements Engineering
 - ML Use-Cases Priorization
 - Data Availability Check
- MODEL DEVELOPMENT**
 - Data Engineering
 - ML Model Engineering
 - Model Testing & Validation
- OPERATIONS**
 - ML Model Deployment
 - CI/CD Pipelines
 - Monitoring & Triggering

<https://ml-ops.org/content/mlops-principles>



[Pay Attention to What You Need: Do Structural Priors Still Matter in the Age of Billion Parameter Models? \(neurips.cc\)](#)

[Introducing Pathways: A next-generation AI architecture \(blog.google\)](#)

Enabling Autonomy for Deep Space Planetary Science

- Greater perception and autonomy can maximize science and mission return
- Sustainable deep learning for planetary science requires a holistic approach to user needs, data, software, flight hardware, and models



- Please reach out for a demonstration of our software in a lunar analogue environment
- Stay tuned for the first commercial demo of deep learning on the lunar surface in 2023



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linktr.ee/missioncontrol