2025 Universities Space Research Association (USRA) Symposium
Artificial Intelligence for Space and Aeronautics: Research and Development for Evolving Missions
27 March 2025.

AI for Science (Space)

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Jet Propulsion Laboratory
California Institute of Technology

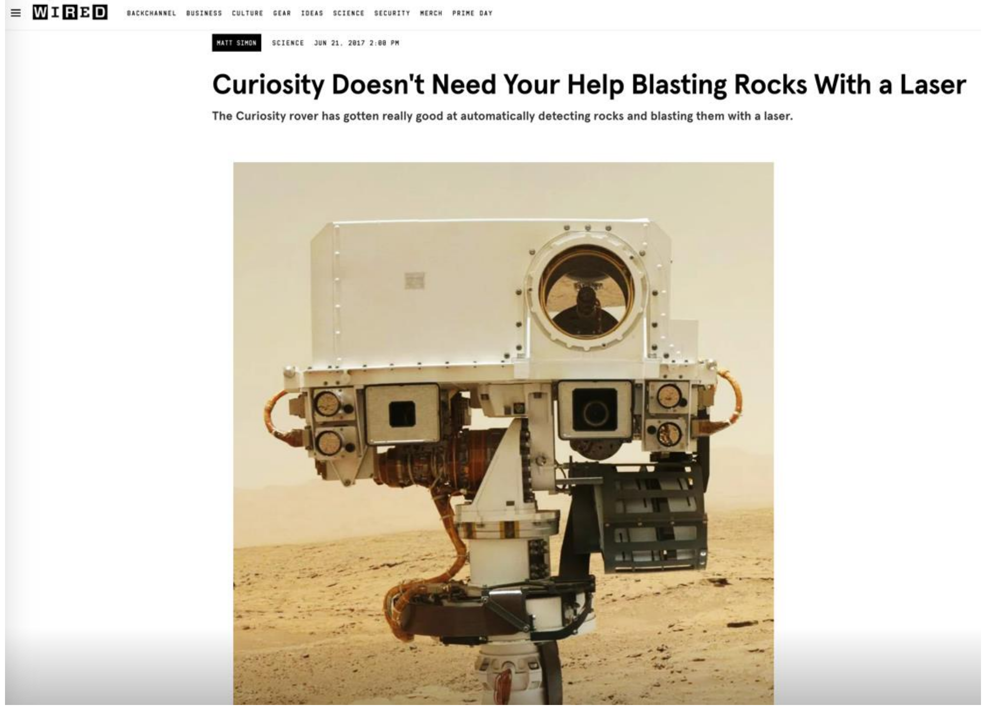
Where we’ve been…

Where we are…

Where we’re going…

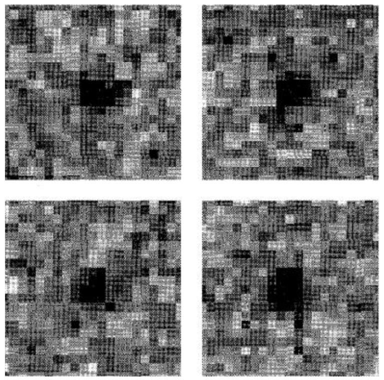
Where we've been:

AI has been in use for Decades



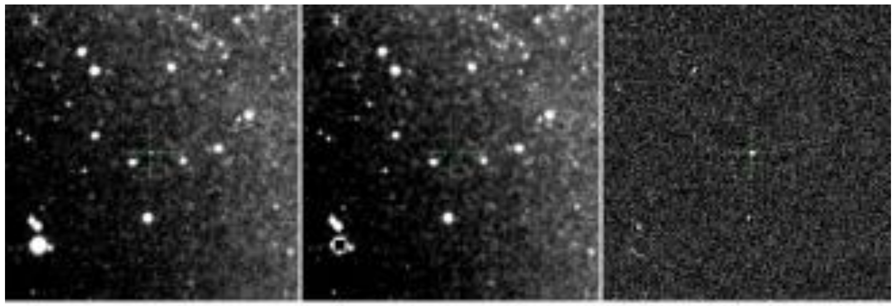
…although a small proportion of its potential impact….

ML in Astronomical Surveys – Representative Examples



1993: ML used for 2nd Mt Palomar Sky Survey (POSS-2)

- Bootstrap to classify fainter objects
- Fayyad et al. ICML 1993; Weir et al. 1995 Astr Soc Pac

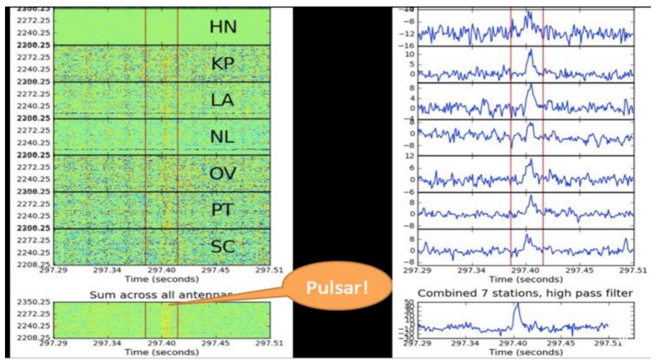


Machine learning is used for optical astronomy to **triage <u>millions of optical events nightly</u>**

Intermediate Palomar Transient Factory (i-PTF)
[Waszczak et al. 2017 Astr Soc Pac]

Zwicky Transient Facility (ZTF)
[Mahabal et al. 2019 Astr Soc Pac, Masci et al. 2019 Astr Soc Pac]

Science (left) and reference (center) images used with Machine Learning to find true astronomical transient and variable objects (right). -- U. Rebbapragada/JPL



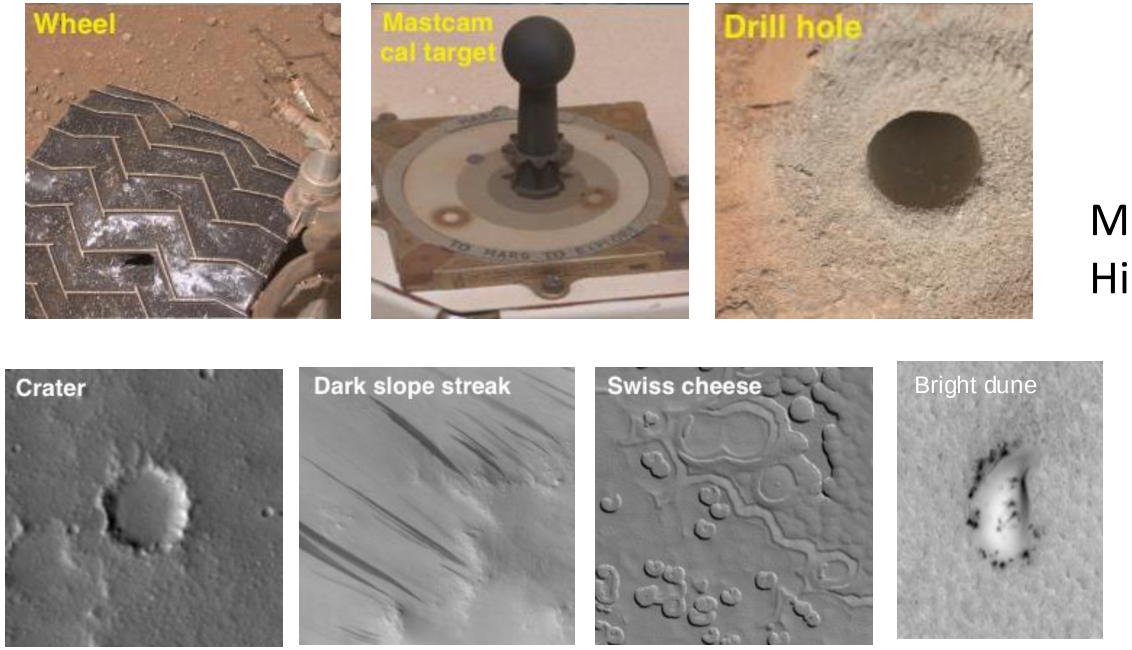
Machine Learning for Automated Triage/Classification of Radio Transient Events

Very Long Baseline Array (VLBA)
Fast Transients Experiment (V-FASTR)

Wagstaff and Thompson/JPL
Wagstaff et al. 2016 Astr Soc Pac

For a review see: S. G. Djorgovski, A. A. Mahabal, M. J. Graham, K. Polsterer, A. Krone-Martins, "Applications of AI in Astronomy," in Artificial Intelligence for Science, https://arxiv.org/abs/2212.01493

ML for Semantic Indexing of Imagery



MSLNet
HiriseNet [Wagstaff et al. AAAI 2018, 2021]

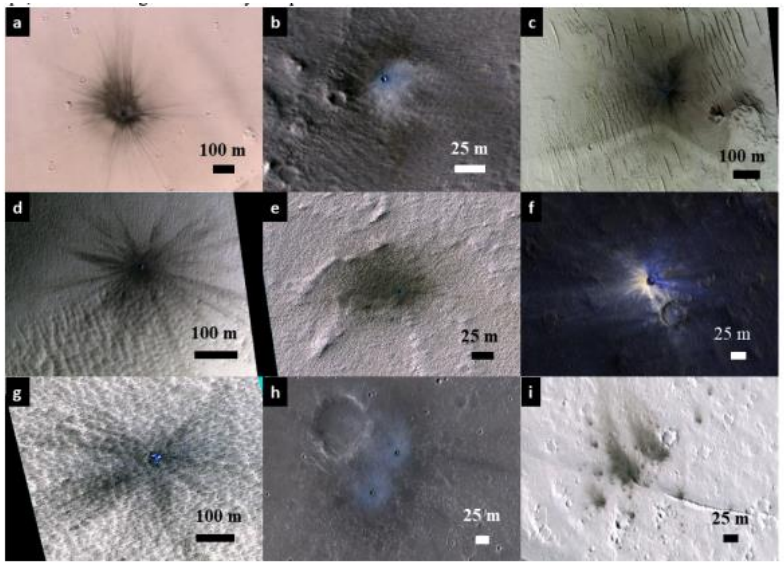


Figure 1. Albedo features around new dated impacts on Mars. Row 1: dual-toned single craters; (a) ESP_048888_1735: linear rays and a halo; (b) ESP_037544_2060: halo; (c) ESP_031965_2050: halo, linear, and arcuate rays. Row 2: single craters; (d) ESP_062128_1725: dark-toned linear rays; (e) ESP_017821_1820: dark-toned halo; (f) ESP_030566_1860: light-toned linear rays and a diffuse halo. Row 3: clusters of craters; (g) ESP_016954_2245: exposed ice and dark-toned linear rays; (h) ESP_053006_1980: dual-toned blast zone, halos, rays; (i) ESP_047175_1955: dark-toned blast zone, halos, rays. The left column have rays, the middle column have halos, and the right column have rays as well as halos. Images are from HiRISE enhanced-color RDRs, stretched for contrast, with North up. Image credit: NASA/JPL/U of A.

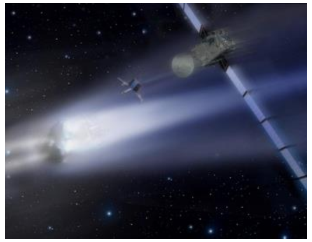
Illustrative NOT exhaustive!

Fresh Impact Crater Detection
[Daubar et al. JGR Planets 2022]
[Wagstaff et al. Icarus 2022]

Automated Scheduling for Space Missions

- Numerous deployments, including to operate $B missions/enterprises


SPIKE for Hubble Space Telescope 1993! [Johnston, Miller et al. Intelligent Scheduling 1993]
SPIKE used for all 4 “great observatories” Hubble, Spitzer, Chandra, Compton
SPIKE now in use for JWST scheduling! [Giuliano, Rager, Ferdous 2023 IWPSS]



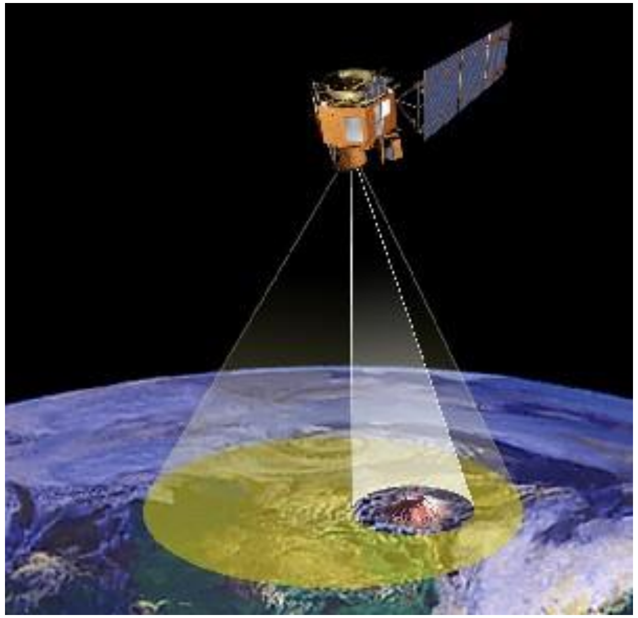
ESA/Rosetta [Chien et al. 2021 JAIS],
Deep Space Network [Johnston et al, 2014 AIMag],
NISAR [Doubleday 2016 SPIE]

Numerous other missions: Earth Observing One [Chien et al. 2005 JACIC], Orbital Express [Knight et al. 2014 AIMag],
ECOSTRESS [Yelamanchili et al. 2021 SpaceOps], OCO-3 [Yelamanchili et al. 2021 Spaceops], EMIT [Maillard et al. 2023 IWPSS],
see many more in [Chien et al. 2012 SpaceOps] e.g. DATA-CHASER, Fuse, Subaru, Cluster 2 WBD, Mars Express, TANDEM-SAR-X, Planet Dove, Planet Skysat, …
Future missions in development baselining AI scheduling: Europa Clipper, Surface Biology and Geology (SBG) and in study: SDC

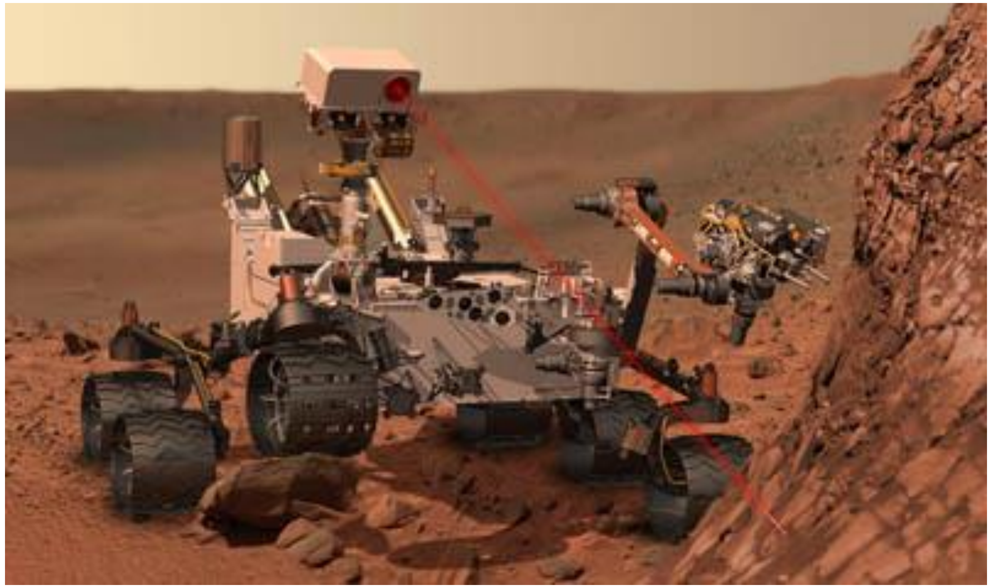
But still a tiny fraction of total applicable space missions…

Illustrative NOT exhaustive!

Several Operational Flights of AI



- Autonomous Sciencecraft on Earth Observing One 2003-2017 [Chien et al. 2005 JACIC]
  - Onboard Planning
  - ML for science analysis [Doggett et al. 2005 RSE]



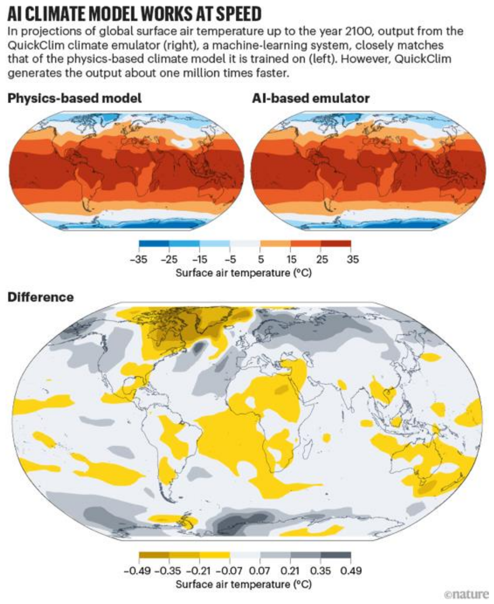
- AEGIS Autonomous Targeting on MER, MSL, M2020 [Francis et al. 2017 Sci Rob]

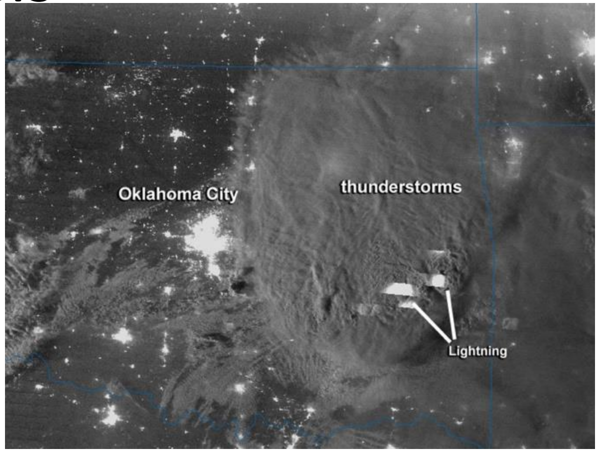
Where we are:

AI increasingly used as a modeling tool

Example (NOT exhaustive)

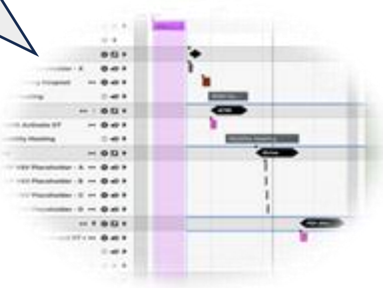
- Climate (CLIMA) T. Schneider et al. [Nature (News) March 2024]
- Weather [McGovern et al. Natural Hazards 2024]
- Wildfire digital twins and foundation models [Many!]





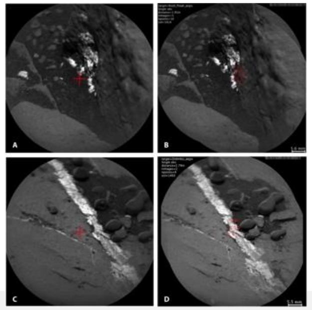
M2020/Perseverance: AI for Science

Onboard Planner

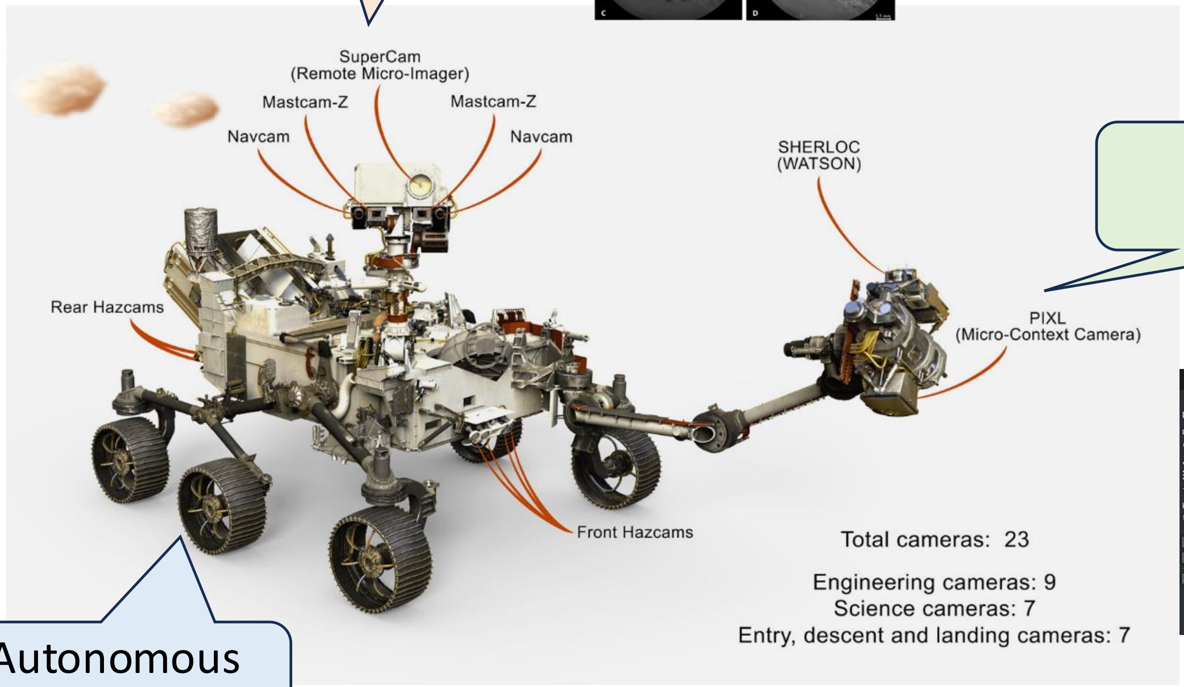


Gaines et al. 2023 ASTRA
Verma et al. 2023 Sci Rob

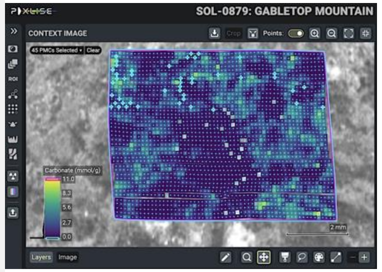
AEGIS Autonomous Targeting



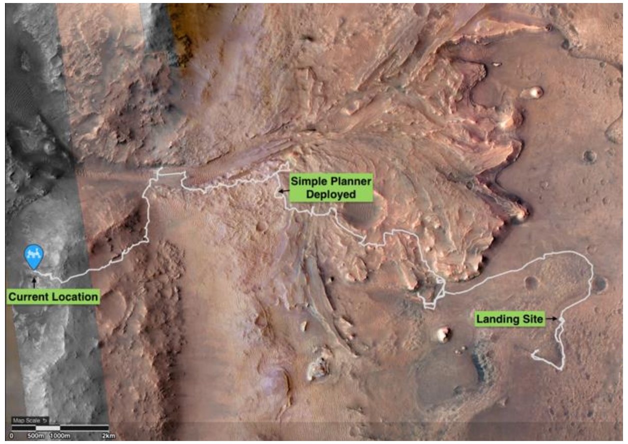
Francis et al. Sci Rob 2017



PIXL Adaptive Sampling



Lawson et al. 2025 Icarus



Enav Autonomous Driving

Verma et al. 2023 Sci Rob

Where we’re going:

(I hope!)

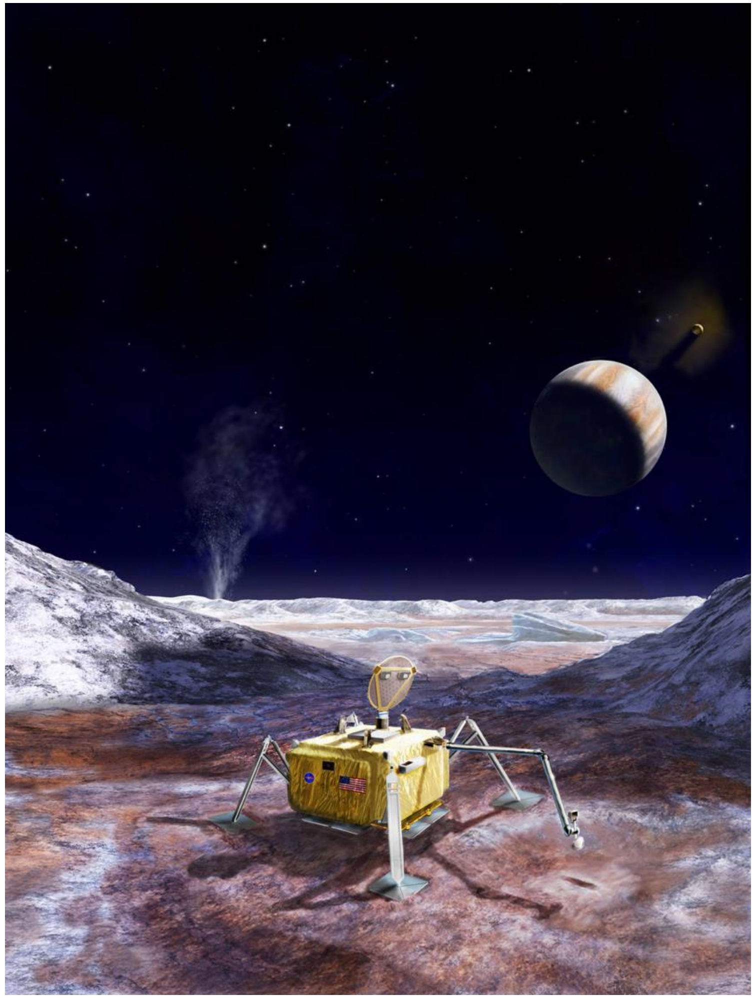
ENGINEERING

How NASA's Search for ET Relies on Advanced AI

Jet Propulsion Laboratory's artificial intelligence chief describes the “ultimate” test for AI in space exploration

By Larry Greenemeier on December 28, 2017

AI is Central to Ambitious Space Mission Concepts to *Find Life Beyond Earth*

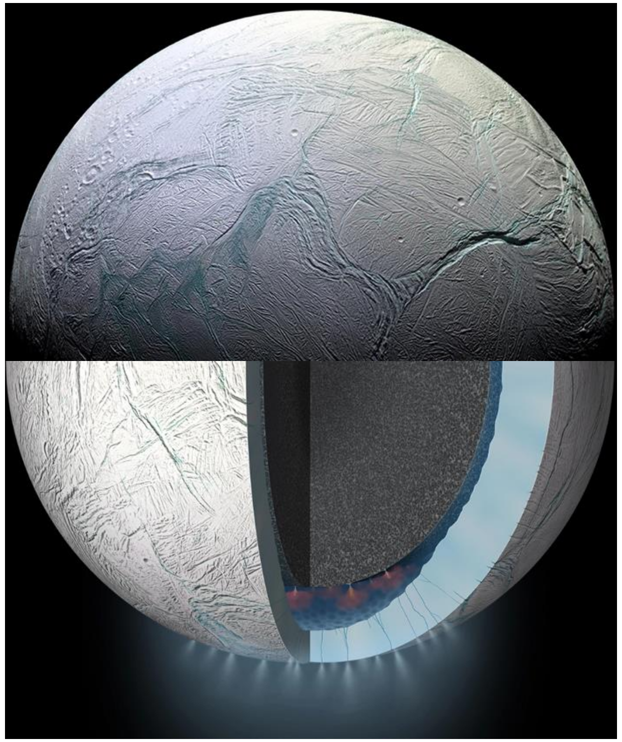


Europa Lander Mission Concept
Matanuska Glacier Field Trials (2022)
Decision Theoretic Planning!
[Chien et al. 2022 ASTRA, Wagner et al. 2023 JAIS]

Robotics – Sampling Autonomy: [Bowkett et al. 2023 IEEE Aero]

JWST CO_2 @ Europa:
[Villanueva et al. 2023 Science]
[Trumbo et al. 2023 Science]

AI is Central to Ambitious Space Mission Concepts to *Find Life Beyond Earth*



Enceladus CO_2 [Brown et al 2006 Science]
Enceladus Phosphates [Postberg et al. 2023 Nature]

Exobiology Extant Life Surveyor (EELS)
[Thakker et al, Talbot et al, Georgiev, 2023 IROS]

Multiple tests on Athabasca Glacier (2022, 2023)

DARE MIGHTY THINGS

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Exemplars but NOT exhaustive!

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  Giuliano, Rager, Ferdous, Invited Talk, International Workshop on Planning and scheduling for Space, Prague, CZ, 2023.
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  Chien SA, Rabideau G, Tran DQ, Troesch M, Nespoli F, Ayucar MP, Sitja MC, Vallat C, Geiger B, Vallejo F, Andres R. Activity-based scheduling of science campaigns for the rosetta orbiter. Journal of Aerospace Information Systems. 2021 Oct;18(10):711-27.
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Early Flight

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Modelling

- Climate Modelling [Nature (News) March 2024]
  https://www.nature.com/articles/d41586-024-00780-8
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AI on Perseverance

- Onboard Planner
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EELS

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