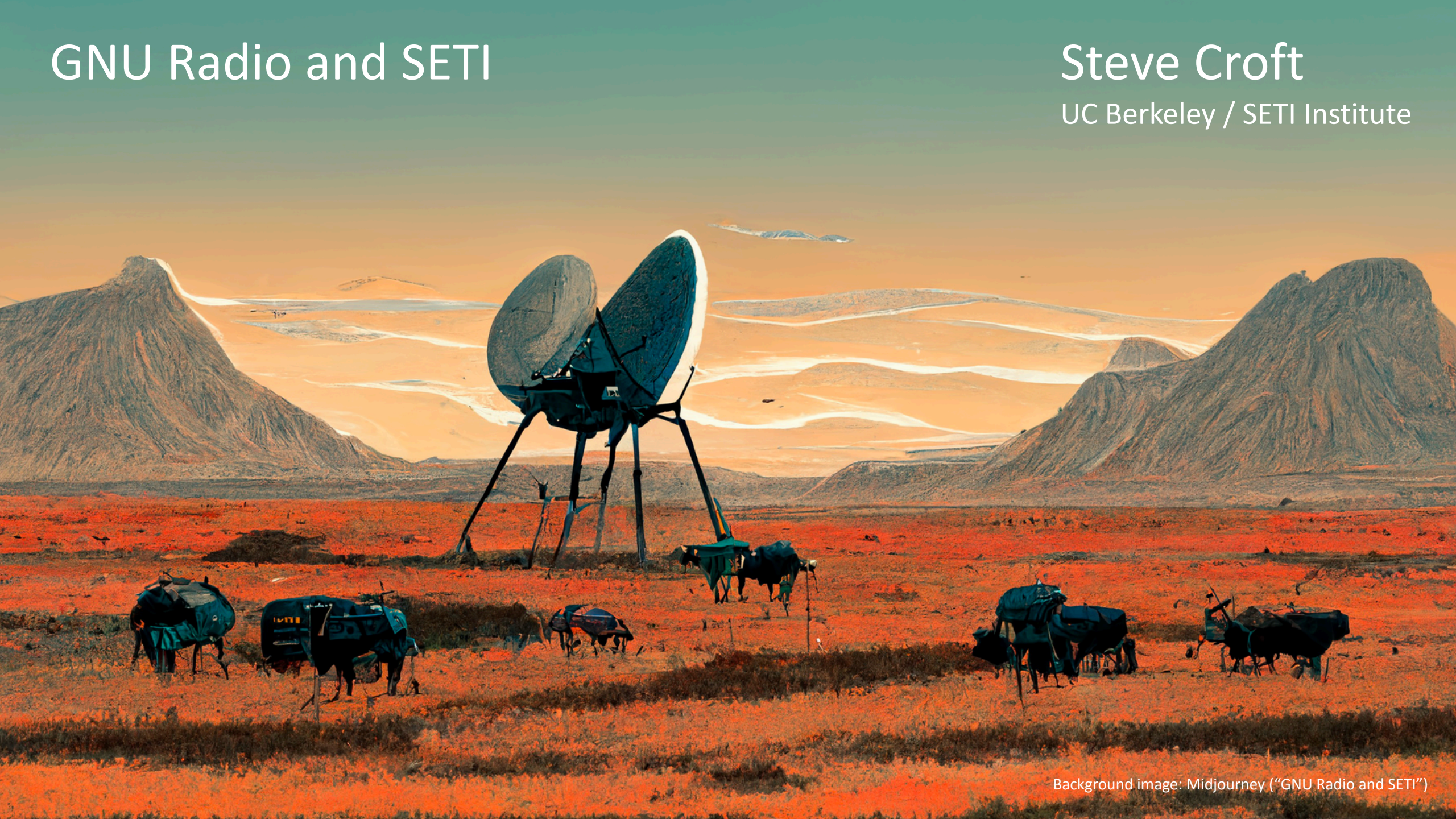
GNU Radio and SETI

Steve Croft
UC Berkeley / SETI Institute



Background image: Midjourney (“GNU Radio and SETI”)

Meetings: Problems of Detecting Extraterrestrial Life: Cambridge (Mass)

19-20 Dec 1958

SEE: ADM: ORG: NAS: Space Sc B Requests for Support: Proposals: Stanford U: Extra terrestrial Contamination & Detection of Life on Other Planets: Lederberg 1959: 13 Apr

National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington 25, D. C.

SPACE SCIENCE BOARD

Meeting on the Problems of
Detecting Extraterrestrial Life

Massachusetts Institute of Technology

December 19 and 20, 1958

Participants:

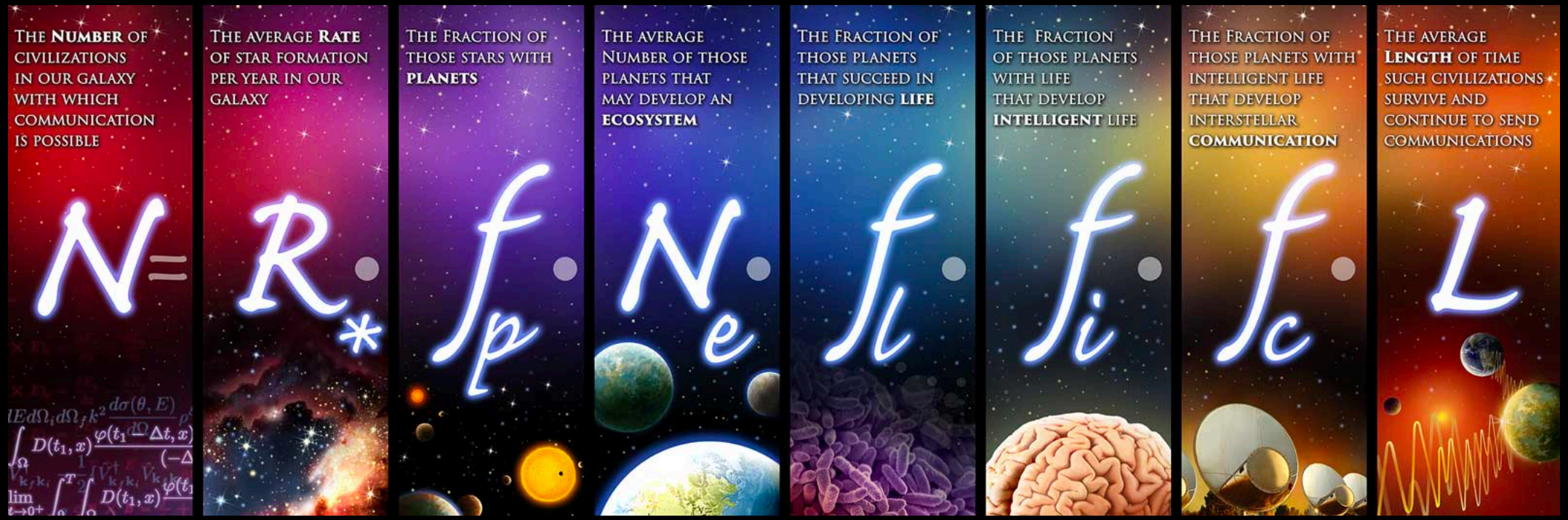
Cowie	Hartline	Miller	Vishniac
Davies	Kamen	Rossi	Billings
Derbyshire	Levinthal	Schmitt	Freeman
Doty	Luria	Sistrom	Young
Gold	MacNichol	Townsend	

Frank Drake

1930 - 2022

A Roadmap for Astrobiology

The Drake Equation:



Technological civilizations | Stars | Planets | Habitable Worlds | Life | Intelligence | Technology | Duration

Planets are *Everywhere!*

Kepler Mission Taught Us That:

Every star in the sky has one or more planets

The majority of planets fall between Mars and Neptune in size – like Earth

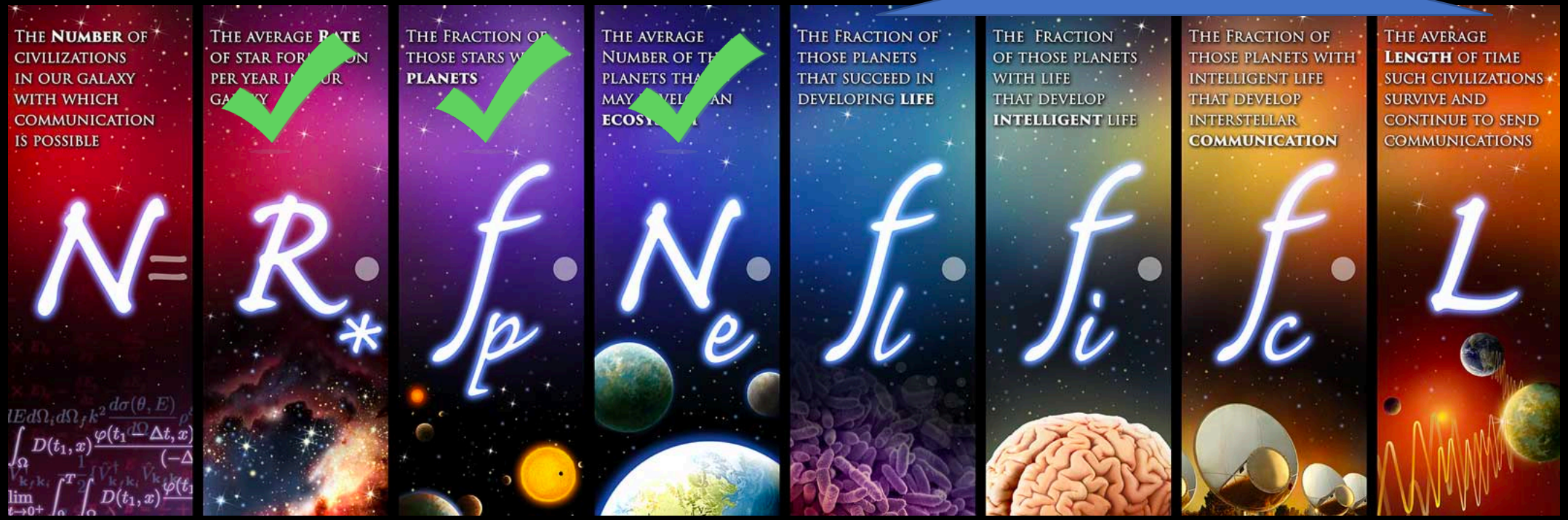
Approximately 20% of all planets are rocky, earthlike, habitable-zone worlds

This means potentially *10 to 60 billion* earthlike, habitable-zone planets in our galaxy alone

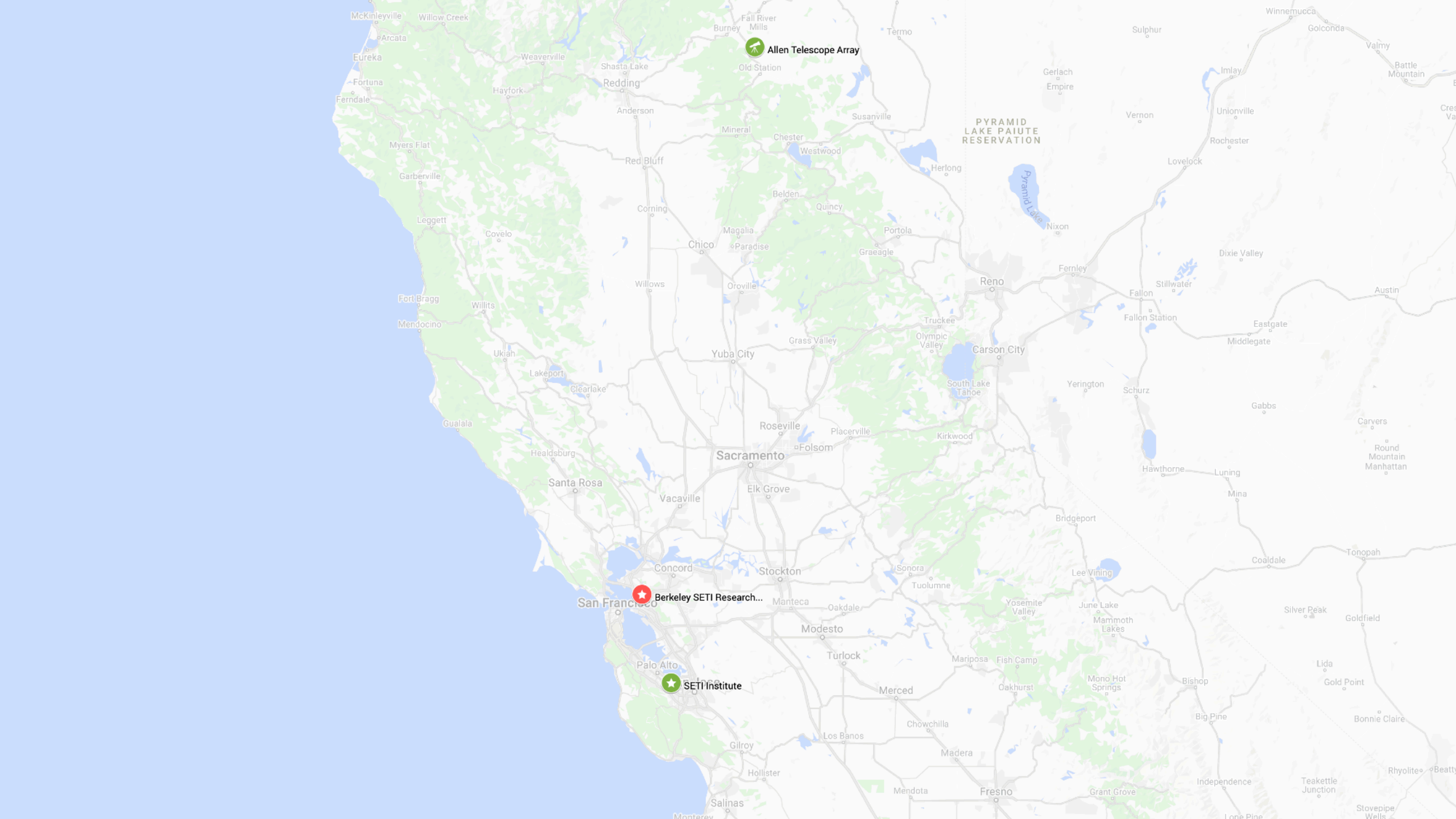
So How Much Do We Know?

?

The Drake Equation:

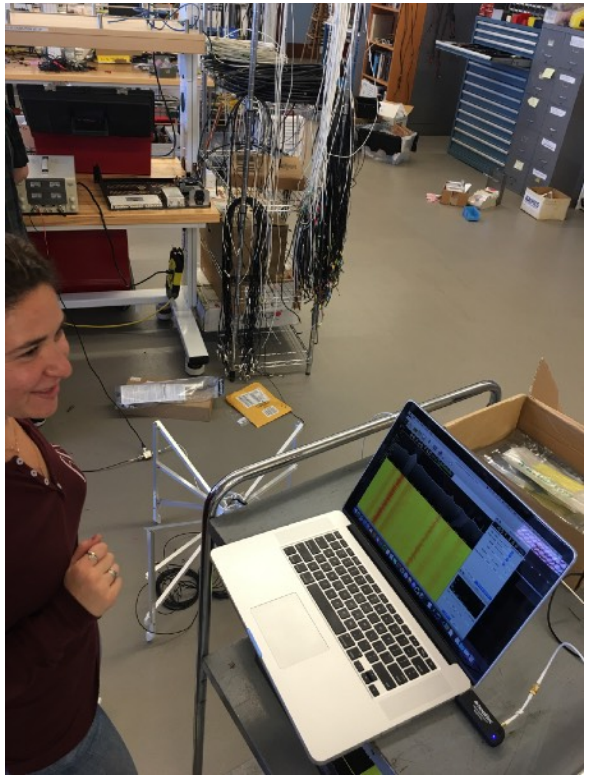


Technological civilizations | Stars | Planets | Habitable Worlds | Life | Intelligence | Technology | Duration


Allen Telescope Array
Berkeley SETI Research...
SETI Institute
PYRAMID LAKE PAIUTE RESERVATION
Pyramid Lake
McKinleyville
Willow Creek
Arcata
Eureka
Fortuna
Ferndale
Fall River Mills
Burney
Termo
Sulphur
Winnemucca
Golconda
Valmy
Battle Mountain
Weaverville
Shasta Lake
Old Station
Redding
Hayfork
Gerlach
Empire
Imlay
Anderson
Susanville
Vernon
Unionville
Rochester
Mineral
Chester
Westwood
Lovelock
Myers Flat
Red Bluff
Herlong
Garberville
Belden
Quincy
Corning
Leggett
Covelo
Magalia
Paradise
Portola
Graeagle
Chico
Nixon
Dixie Valley
Fernley
Reno
Willows
Oroville
Stillwater
Fallon
Austin
Fort Bragg
Willits
Fallon Station
Truckee
Eastgate
Mendocino
Olympic Valley
Middlegate
Grass Valley
Yuba City
Carson City
Ukiah
Lakeport
South Lake Tahoe
Yerington
Schurz
Clearlake
Gabbs
Roseville
Placerville
Kirkwood
Gualala
Folsom
Carvers
Sacramento
Round Mountain
Manhattan
Healdsburg
Hawthorne
Luning
Santa Rosa
Elk Grove
Mina
Vacaville
Bridgeport
Tonopah
Concord
Stockton
Sonora
Coaldale
Lee Vining
Tuolumne
Manteca
Yosemite Valley
June Lake
Oakdale
Mammoth Lakes
Silver Peak
Goldfield
Modesto
Turlock
Mariposa
Fish Camp
Palo Alto
Oakhurst
Mono Hot Springs
Lida
Bishop
Gold Point
Merced
Big Pine
Chowchilla
Bonnie Claire
Los Banos
Gilroy
Madera
Hollister
Independence
Teakettle Junction
Rhyolite
Mendota
Fresno
Grant Grove
Salinas
Stovepipe Wells

BREAKTHROUGH LISTEN

BERKELEY SETI RESEARCH CENTER



BERKELEY SETI RESEARCH CENTER

BREAKTHROUGH LISTEN

NSF

seti.berkeley.edu/Internship.html

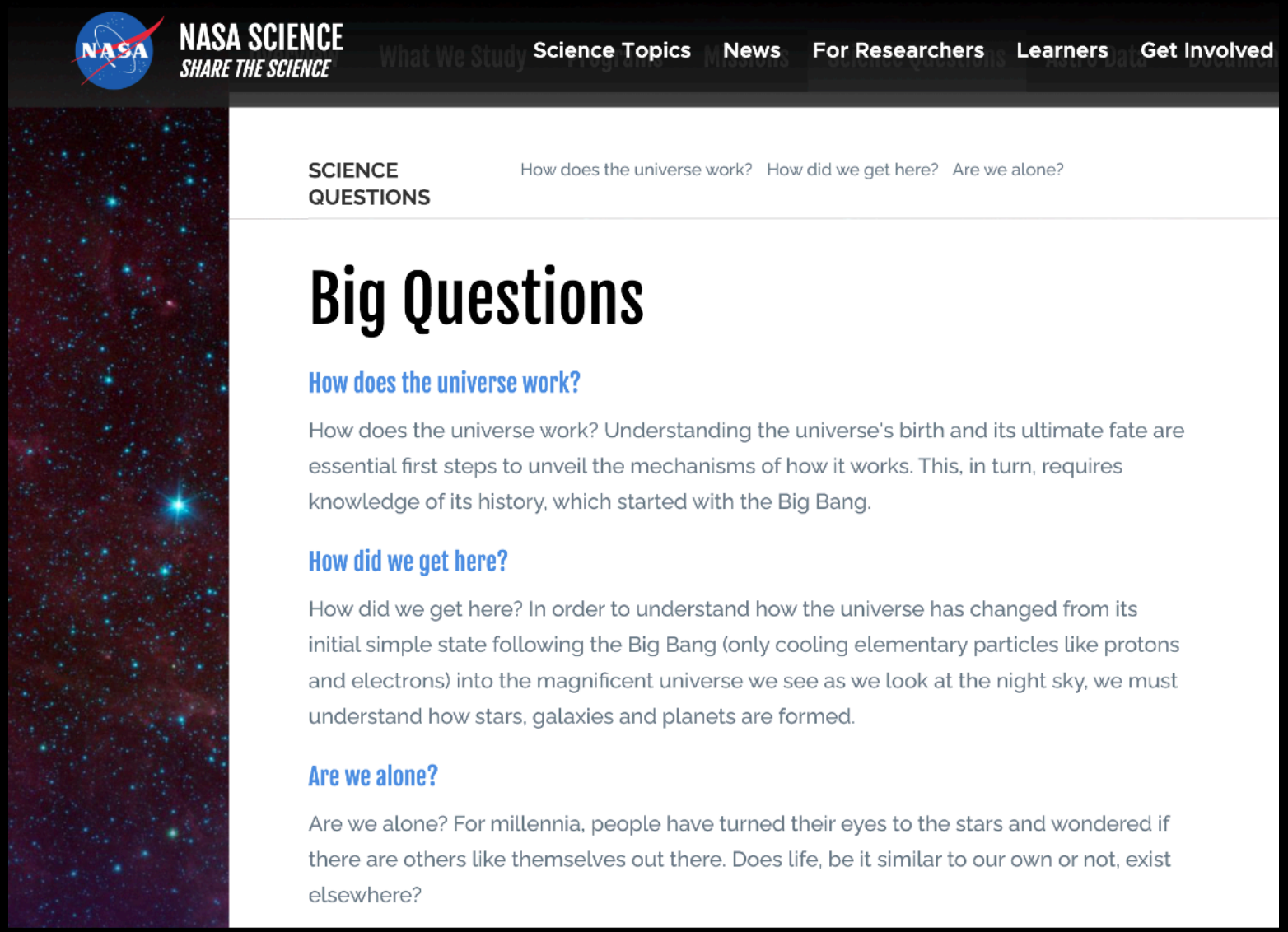

SETI
INSTITUTE
2B

The SETI Institute

Our Mission:

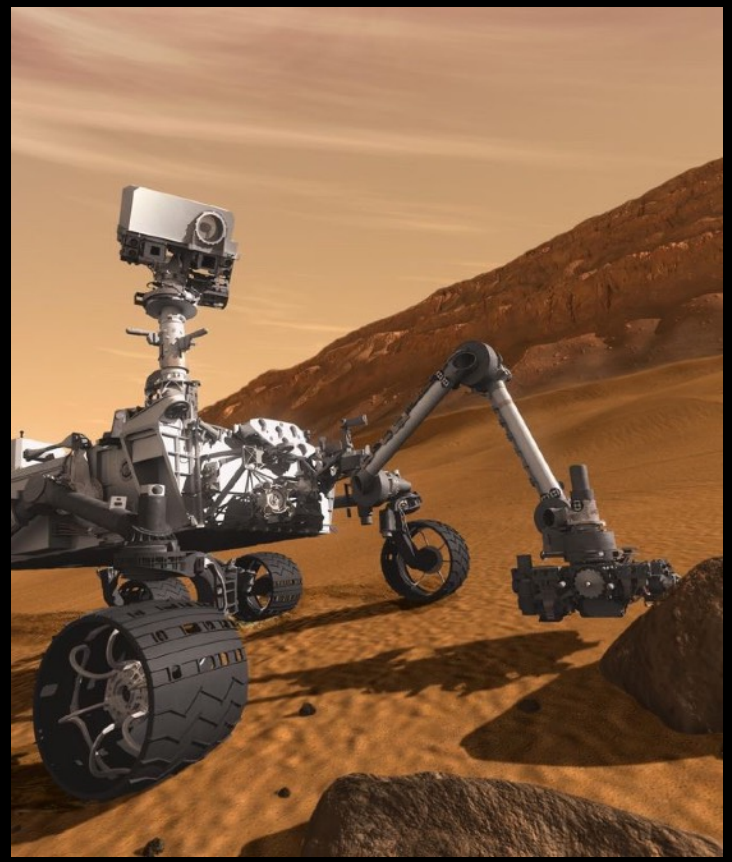
To lead humanity’s quest to understand the origins and prevalence of life and intelligence in the Universe and share this knowledge to inspire present and future generations


Are we alone?



NASA Wants to Know…

And Now – For The First Time…

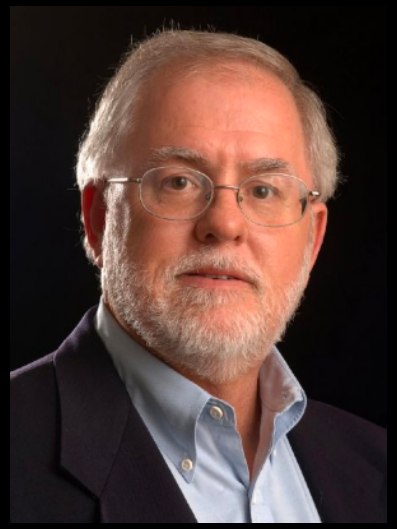


We have the Tools & Technology to Find Out!

Organization

Research - To Explore
Education - To Inspire
Outreach - To Engage

Institute Facts and Figures



Founded in 1984 by Jill Tarter and Tom Pierson at the NASA Ames Research Center
More than 90 PhD Research Scientists and 50 Research Affiliates
10 Professional Staff in Education, Communications and Outreach
126 Total Staff, Headquartered in Mountain View, CA
~ $25M Annual Operating Budget
~ 85% of funding from Federal grants and contracts

Serve as prime contractor to NASA for Planetary Protection
Manage and Operate the Allen (Radio) Telescope Array (ATA) in Northern California
Administer and Manage Education Programs in Partnership with NASA and NSF
Develop Formal and Informal Curriculum Materials for Education Programs
Actively Engage in Public Outreach to Share Our Science with the General Public

Bill Diamond
President and CEO

Bruce Campbell
Chief Financial Officer

Steve Bourdow
Director of Development

Steve Brockbank
Director, Information Technology, Security, & Facilities

Nathalie Cabrol
Director of the Carl Sagan Center

Pamela Harman
Director of Education

SETI INSTITUTE

Debbie Kolyer
Director of Grants Administration

Ly Ly
Director of Communication Services

Rebecca McDonald
Director of Communications

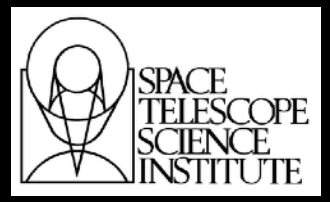
Arminé Saroian
Director of Human Resources

Andrew Siemion
Director of SETI Research

Seth Shostak
Senior Astronomer

Simon Steel
Senior Director of Education and Outreach

Funding Sources, Collaborators, Partners



A Structured Approach

One Question

Are We Alone In the Universe?

Three Domains

Structure of the Universe

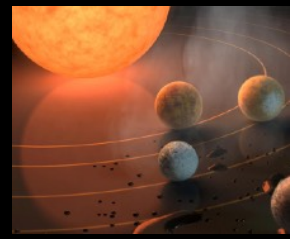
Planets and Habitability

Life, Complexity & Intelligence

Six Disciplines

Astrophysics
Exoplanets

Planetary Exploration
Astrobiology
Climate & Geoscience



Radio and Optical Technosignatures

What we do

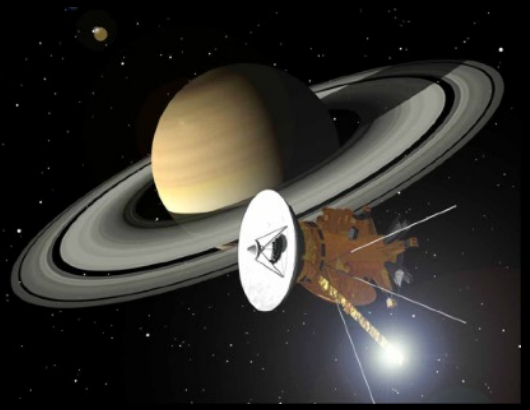
Research Across the natural sciences:

- NASA Science Mission Support
- Field Expeditions
- Laboratory Research
- Ground-based Observations – Radio/optical
- Space-based Observations – Hubble, Kepler, TESS…
- Technology and Instrumentation Development
- Advanced data analytics and data management

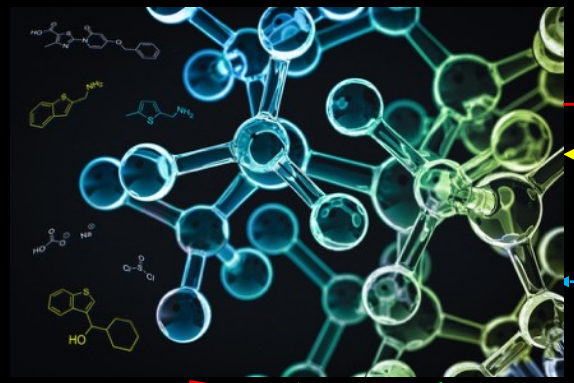
We explore to understand :

- Stellar and planetary evolution
- Planetary environments and habitability
- The nature and origins of life
- The evolution of intelligence and technology

A Day at the Office…



Chemistry



Physics

Biology

Astronomy

Geology

Climate Science

Planetary Science


SETI INSTITUTE
GNU Radio
THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM
www.seti.org/gnu-radio-and-seti
Photo: Arash Roshanineshat


EXIT

Wiki Home
GNU Radio Website
FAQ

Guides
Tutorials
Installing GNU Radio
Contributing

Wiki Tools
Recent changes
Random page
Help

Tools
What links here
Related changes
Special pages
Printable version
Permanent link
Page information

GNURadio@theATA

The Allen Telescope Array (ATA) is a 42-element radio telescope array located in Hat Creek, California, operated by SETI Institute. In an effort to increase accessibility to the array among potential users outside the astronomy community, we are working to integrate the array into GNU Radio software. We plan to start out by connecting USRPs to two ATA antennas and developing control, backend, and beamformer software. In addition to this, we are using a discone antenna connected to a USRP and OmniSig software to analyze radio frequency interference (RFI) at the ATA site.

Contents [hide]

1 General Info
  1.1 GNU Radio Testbed
  1.2 Resources on the ATA and friends
  1.3 Useful Radio Astronomy Tools
2 GNU Radio / SETI Hackathon
3 Connecting to VNC on ATA gnuradio machines
4 Setting up the software
5 Observing with the ATA -- Tutorials linked here
6 Public Data

General Info [edit]

GNU Radio Testbed [edit]

GR-ATA Testbed

Resources on the ATA and friends [edit]

- The Allen Telescope Array, SETI Institute
- Welch et al, 2009, The Allen Telescope Array
- SETI Institute
- Berkeley SETI / Breakthrough Listen
- Berkeley SETI blog on Open Data
- Lebofsky et al, 2019 - Breakthrough Listen public data

Useful Radio Astronomy Tools [edit]

- Radial Velocity / VLSR Calculator -- good for determining the V_LSR of spectral lines in your data
- LAB Survey HI Profile Search -- here you can search for HI data given a source's RA, Dec or galactic coordinates. Good if you want to compare the velocity of the HI line that you measure with some preexisting accurate data to ensure your system is working properly.


EXIT


SETI Institute
Antonio Feed

daniestevez / reu-2022 Public

Code Issues Pull requests Actions Projects Security Insights

main 1 branch 0 tags Go to file Code

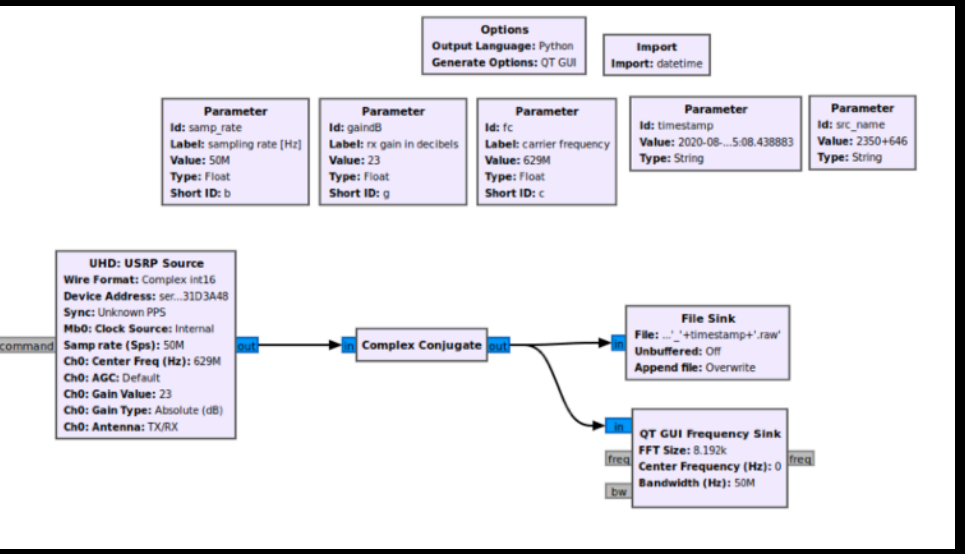
daniestevez Add polyphase filterbank flowgraphs b02a298 on Aug 7 11 commits

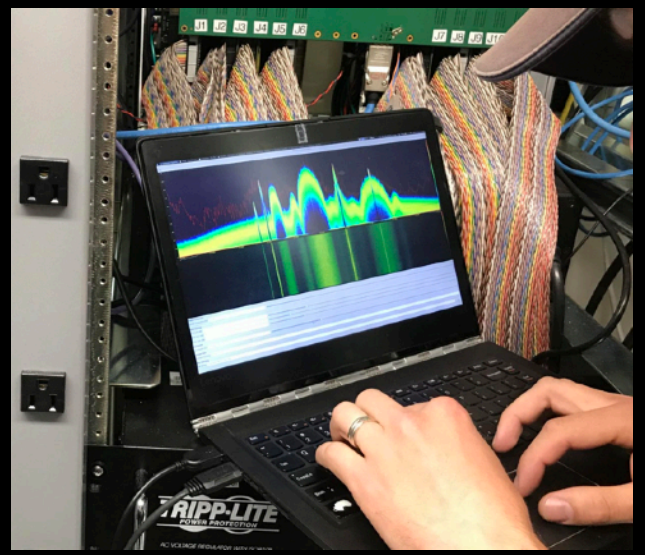
Hydrogen_line	Add materials for HI line observation activity at ATA	2 months ago
broadcast-fm	Add flowgraphs for broadcast FM and VOR using the RTL-SDR	2 months ago
interferometry	Add interferometry flowgraphs	2 months ago
polyphase	Add polyphase filterbank flowgraphs	2 months ago
python-blocks	Add materials for Python blocks session	2 months ago
spectral-analysis	vor-freq-measurement: fix time axis in some GUI time sinks	2 months ago
vor-freq-measurement	vor-freq-measurement: fix time axis in some GUI time sinks	2 months ago
LICENSE	Initial commit	3 months ago
README.md	Add polyphase filterbank flowgraphs	2 months ago

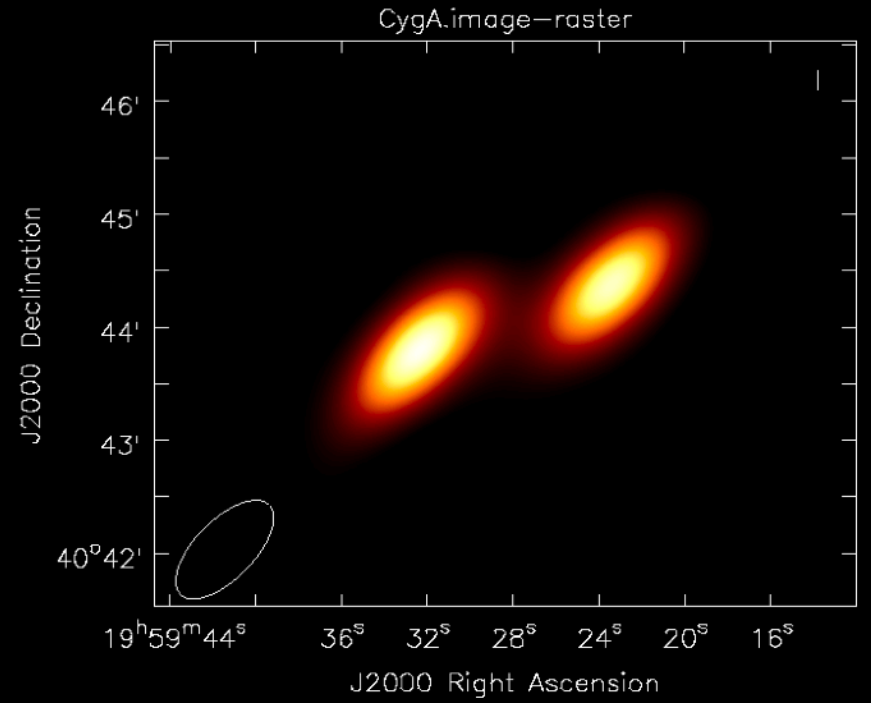
README.md

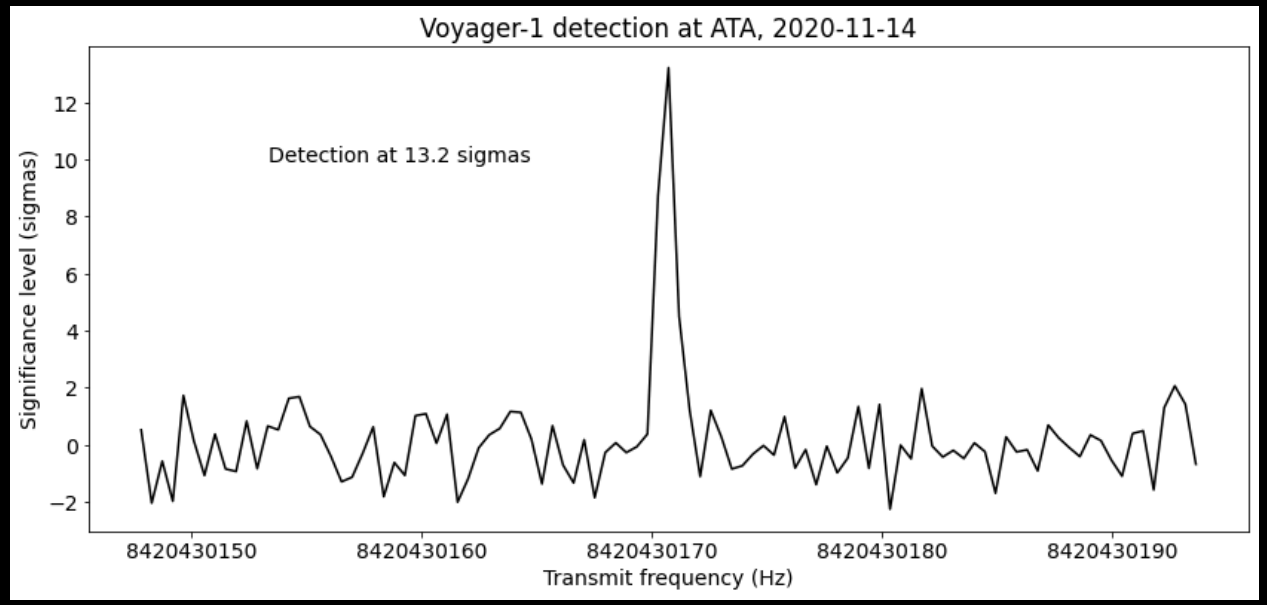
SETI / Breakthrough Listen REU 2022 materials

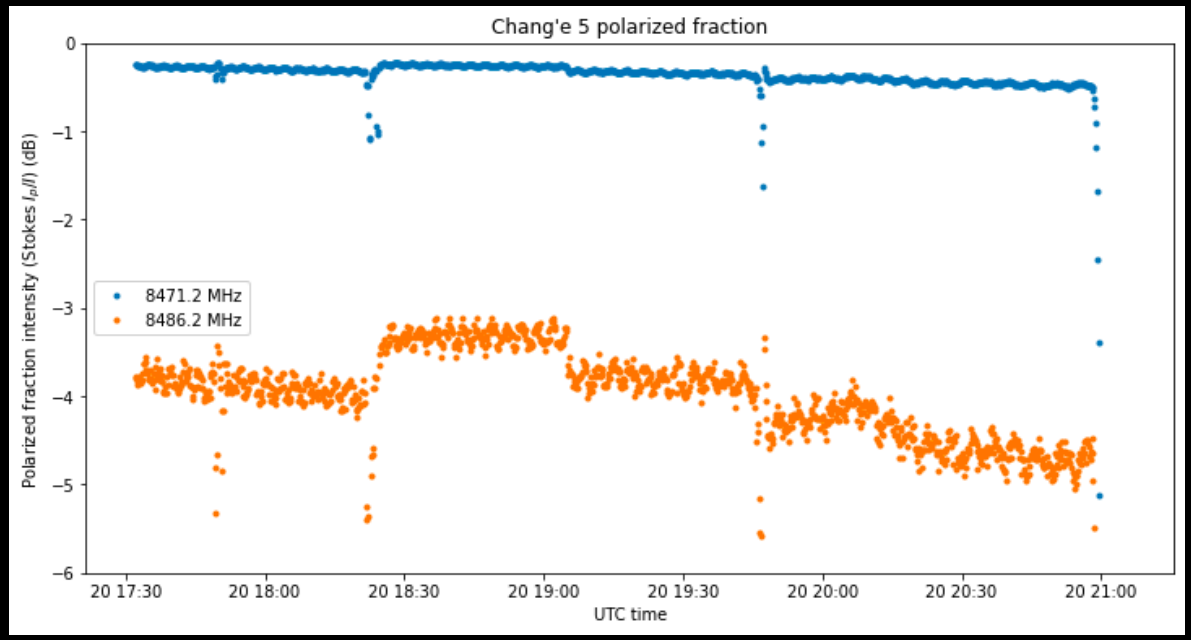
This repository contains miscellanous materials used with the SETI and Breakthrough Listen Research Experience for Undergraduates summer programs. The material was elaborated in the context of the collaboration between GNU Radio and SETI Institute.


Options
Output Language: Python
Generate Options: QT GUI
Import
Import: datetime
Parameter
Id: samp_rate
Label: sampling rate [Hz]
Value: 50M
Type: Float
Short ID: b
Parameter
Id: gaindB
Label: rx gain in decibels
Value: 23
Type: Float
Short ID: g
Parameter
Id: fc
Label: carrier frequency
Value: 629M
Type: Float
Short ID: c
Parameter
Id: timestamp
Value: 2020-08-...5:08.438883
Type: String
Parameter
Id: src_name
Value: 2350+646
Type: String
UHD: USRP Source
Wire Format: Complex int16
Device Address: ser...31D3A48
Sync: Unknown PPS
Mb0: Clock Source: Internal
Samp rate (Sps): 50M
Ch0: Center Freq (Hz): 629M
Ch0: AGC: Default
Ch0: Gain Value: 23
Ch0: Gain Type: Absolute (dB)
Ch0: Antenna: TX/RX
command
out
in
Complex Conjugate
File Sink
File: .../'+timestamp+'.raw'
Unbuffered: Off
Append file: Overwrite
QT GUI Frequency Sink
FFT Size: 8.192k
Center Frequency (Hz): 0
Bandwidth (Hz): 50M
freq
bw


TRIPP-LITE


CygA.image—raster
46'
45'
44'
43'
40°42'
J2000 Declination
19h59m44s
36s
32s
28s
24s
20s
16s
J2000 Right Ascension


Voyager-1 detection at ATA, 2020-11-14
Detection at 13.2 sigmas
Significance level (sigmas)
12
10
8
6
4
2
0
−2
8420430150
8420430160
8420430170
8420430180
8420430190
Transmit frequency (Hz)


Chang'e 5 polarized fraction
Polarized fraction intensity (Stokes Ip/I) (dB)
0
−1
−2
−3
−4
−5
−6
8471.2 MHz
8486.2 MHz
20 17:30
20 18:00
20 18:30
20 19:00
20 19:30
20 20:00
20 20:30
20 21:00
UTC time

D. Estevez

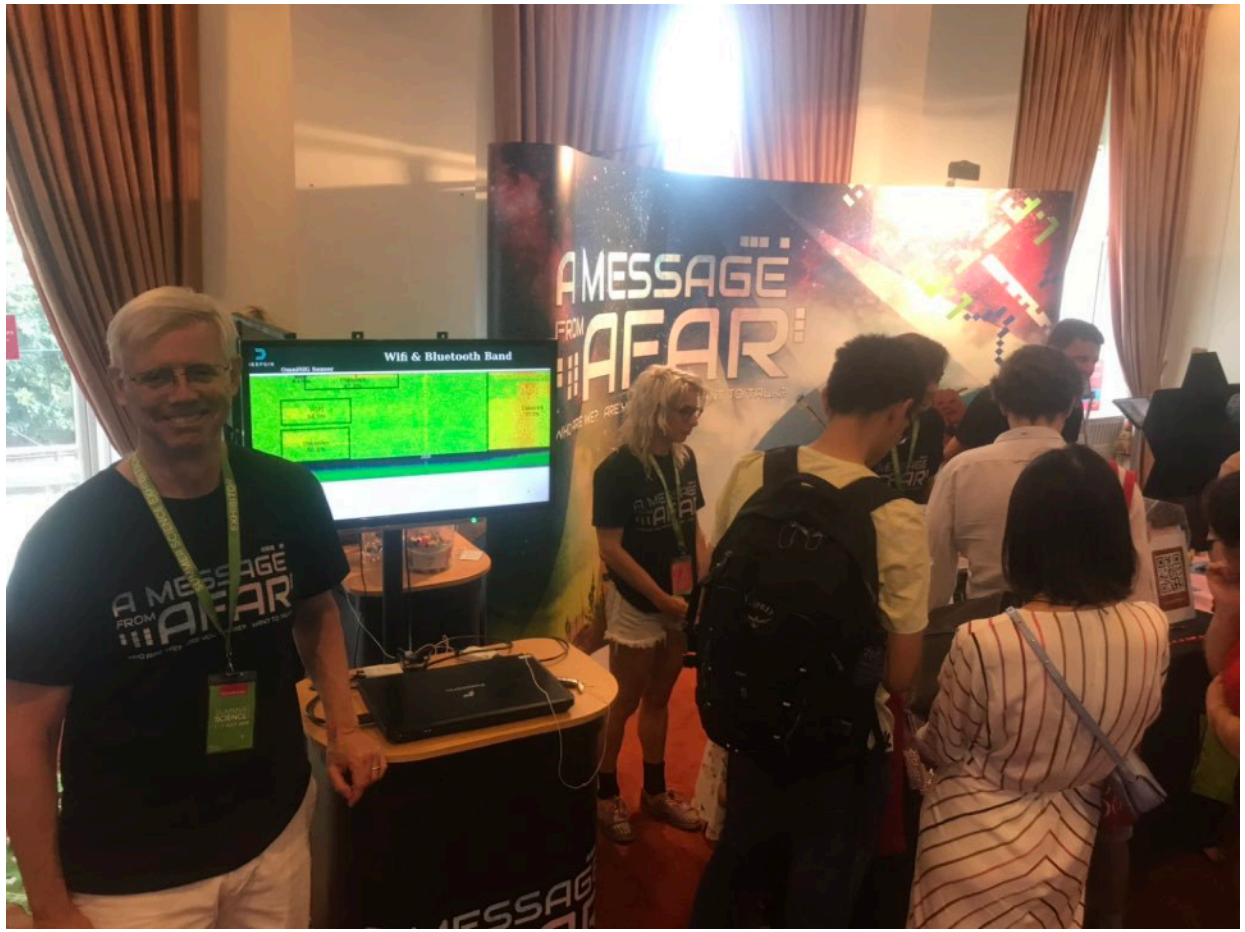
SETI Institute and GNU Radio Join Forces

Sep 8, 2020

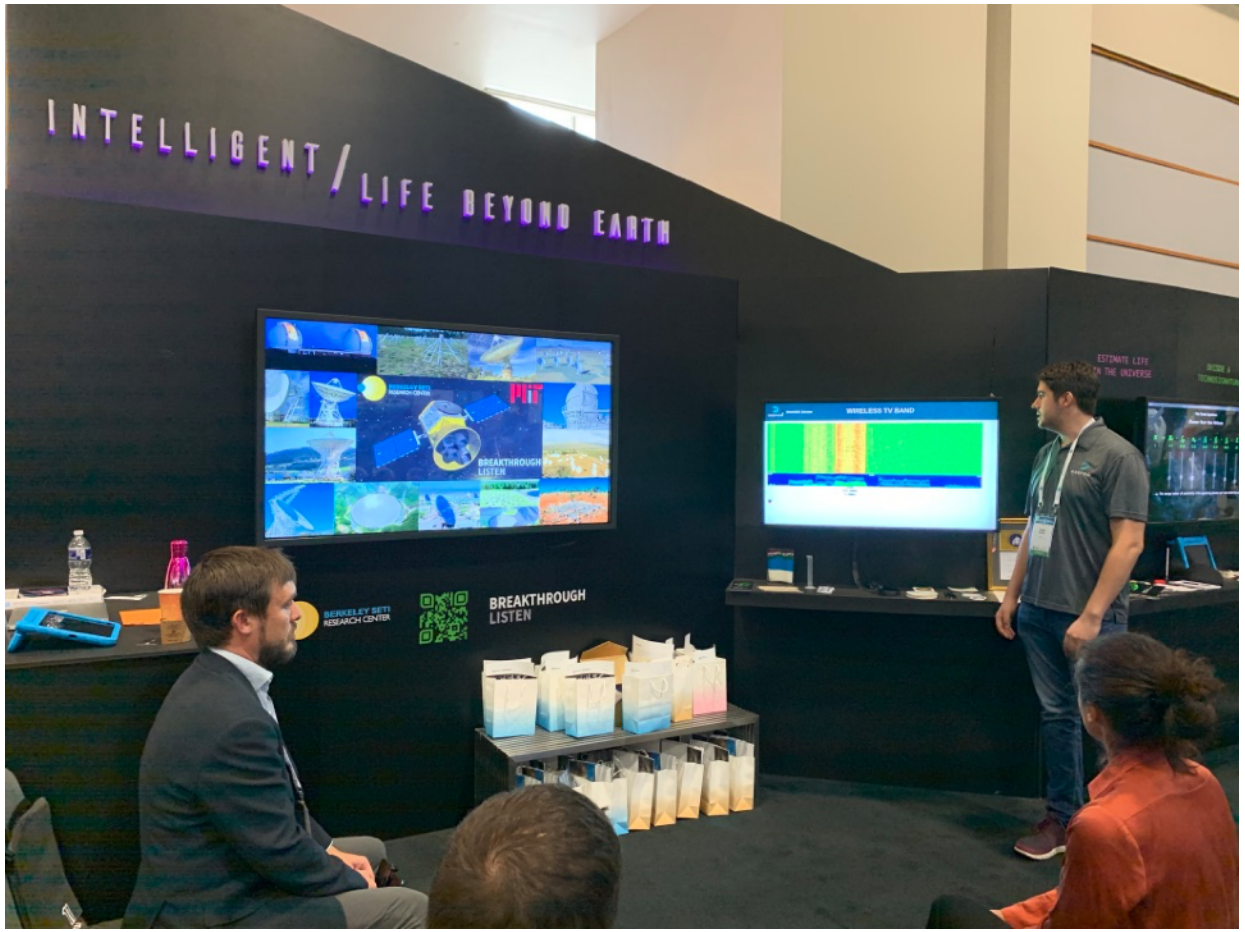
Tags: Press Releases , ATA News , SETI Institute , Partnerships

September 8, 2020, Mountain View, CA – The SETI Institute and GNU Radio are officially joining forces to continue work already underway for signal processing at the SETI Institute's Allen Telescope Array (ATA) at the Hat Creek Radio Observatory (HCRO). This collaboration is an extension of work begun in 2019 to build open-source hardware and software, accessible to both hobbyists and professional SETI scientists, including a GNU Radio module known as gr-ata. Additionally, the SETI Institute will manage contracts and grants for GNU Radio, allowing access to new funding streams to support research and education.

"I first started using GNU Radio as a teaching tool," said Steve Croft, Community Partnership Scientist on the SETI Institute SETI team. "With $25 worth of hardware and some free software, someone with a little technical know-how can begin to explore the radio spectrum - picking up and visualizing FM radio stations, decoding transmissions from airplane transponders, or detecting the signal their car key sends to unlock their vehicle. But I soon discovered there was a whole community of people developing and building cutting-edge devices with this technology, and they welcomed me into their collaboration."



Royal Society Summer Science Exhibition, July 2019



International Astronautical Congress, October 2019

DEEPSIG

BERKELEY SETI RESEARCH CENTER

GNURadio
THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM

BREAKTHROUGH LISTEN

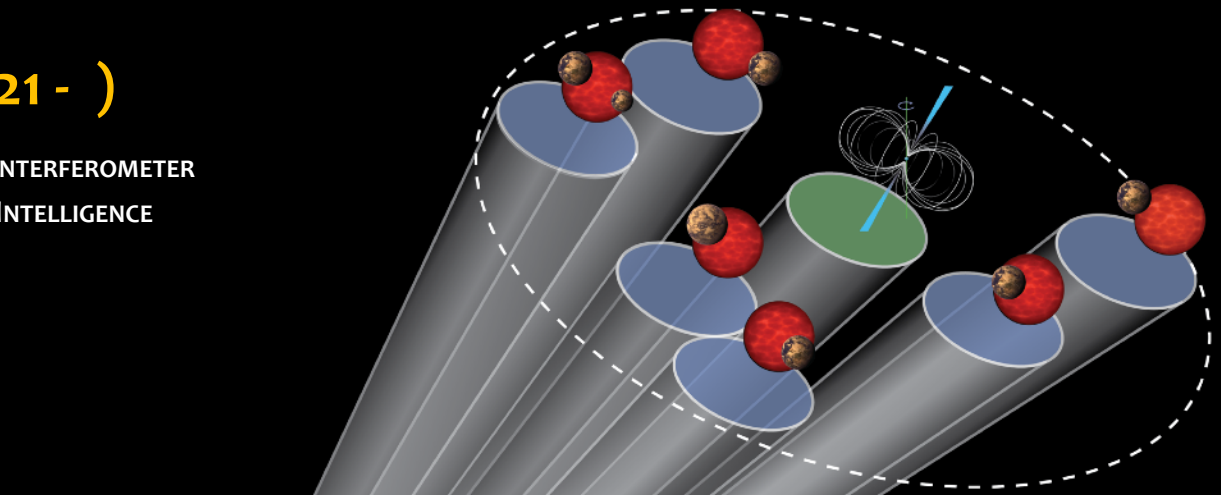
SETI INSTITUTE

Project COSMIC (2021 -)

COMMENSAL OPEN-SOURCE MULTIMODE INTERFEROMETER
CLUSTER SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE

SETI INSTITUTE

NRAO



Jansky VLA (first ever use of VLA for SETI)

Capable of detecting Arecibo radar at 5kpc
(billions of stars)

Primary User Beam

Commensal Beam

Extending our Reach to the World

Big
Picture
Science

‘SETI Talks’ Lectures

Artists in
Residence

www.seti.org

Education Advantage

Airborne Astronomy Ambassadors

NASA Program for High School Science Teachers from Underserved School Districts - 10 Years and running…

Reaching for the Stars

NASA space science for Girl Scouts

In Partnership with the University of Arizona and Astronomy Society of the Pacific

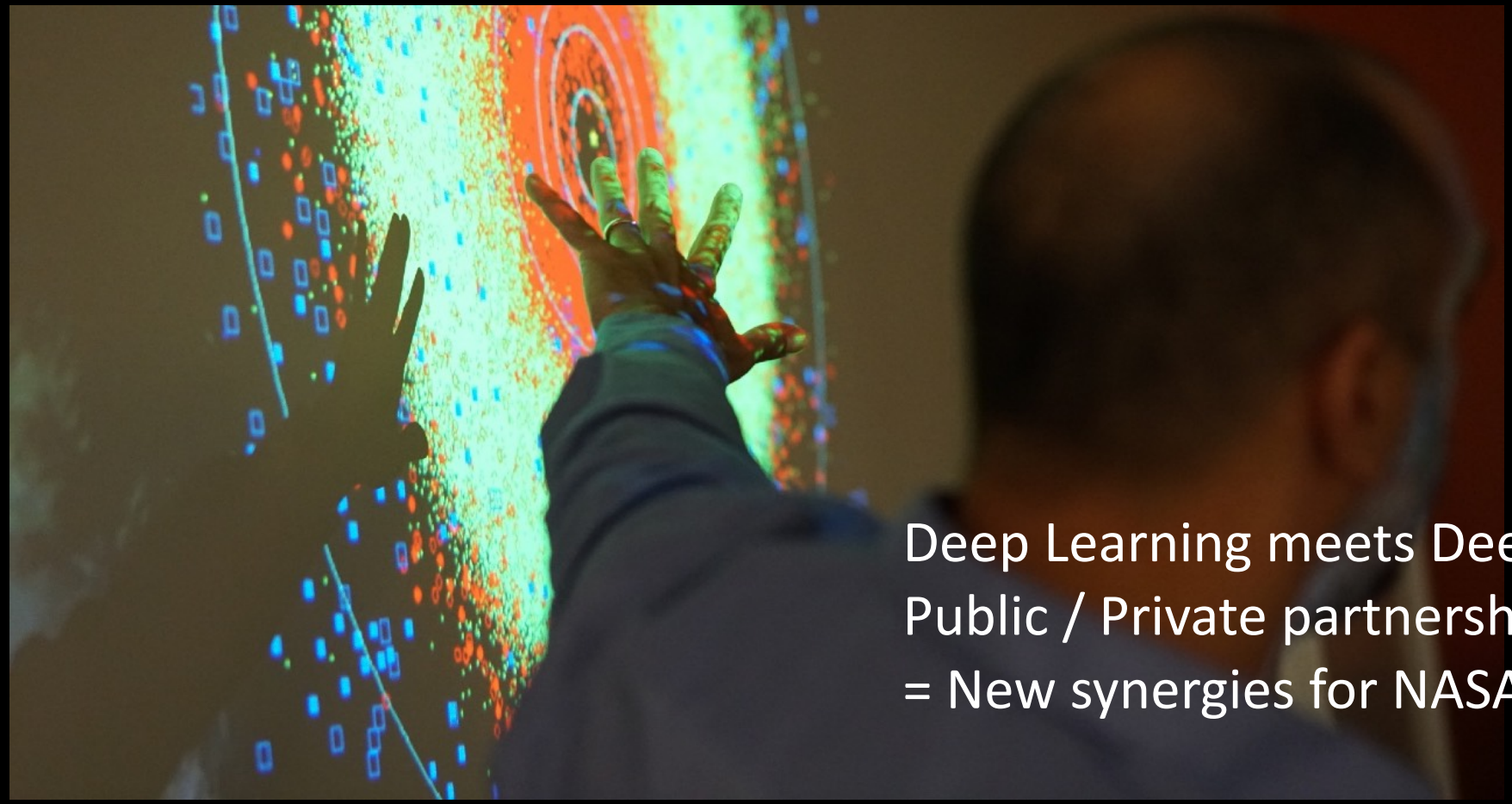
It’s All About *IMPACT*

- AAA for Teachers – Over 200 Alumni and > 40,000 learners reached over the past 9 years
- Demonstrated student gains in standards-based learning and improved attitudes towards STEM subjects and careers
- Over 185 Undergraduate Interns over 15 years
- More than 65,000 young girl scouts completing badge programs in the first year of Reaching for the Stars and > 100,000 in year two…
- New partnerships evolving with Cal Academy, Chabot Space Science Center and the Smithsonian Institute


Frontier Development Lab

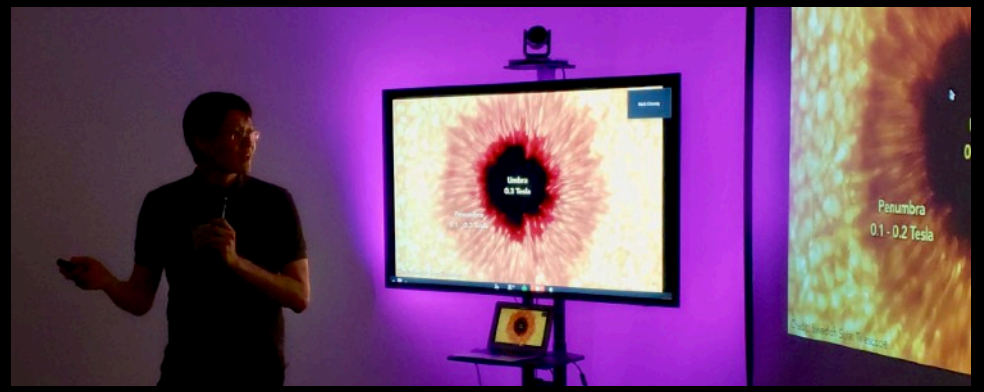
A Public/Private Partnership for AI/ML and Space Science

NASA Frontier Development Lab – At a Glance



Deep Learning meets Deep Science +
Public / Private partnership
= New synergies for NASA research

Frontier Development Lab



Mark Cheung, Lockheed Martin – FDL 2019 'Big Think'

Conceived by the Office of the
Chief Technologist at NASA HQ in
2014/2015 to explore three underlying thesis:

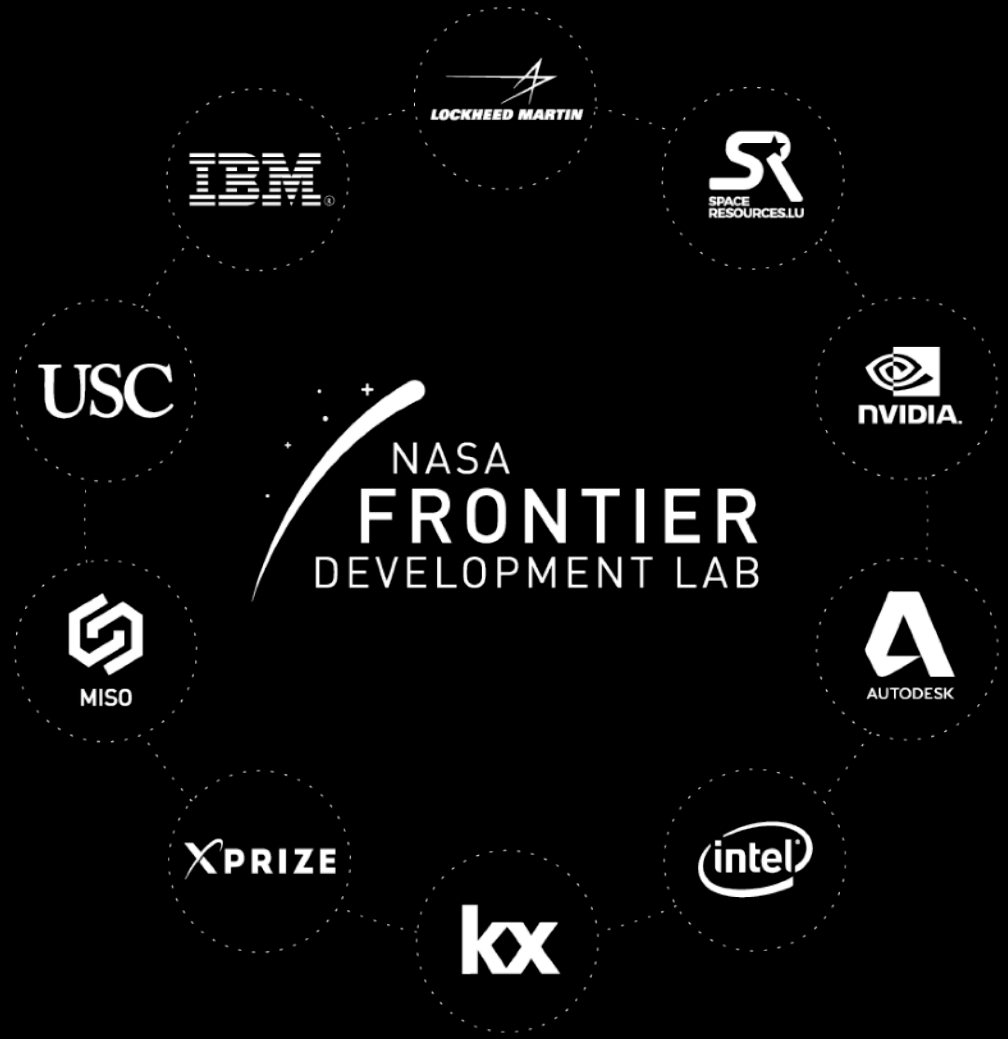
1) Applicability of AI and Machine Learning to NASA Research Priorities

2) Efficacy of Interdisciplinary Teams Working on Short Time Horizons

3) Ability of Public/Private Partnership to Accelerate NASA Objectives – Better, Faster, Cheaper

Who: The Players…

- Early-career PhD's in AI/ML
- Early-career PhD's in Space Research
- AI & Deep Science SME's & Mentors
- NASA Stakeholders
- Industry Partners
- Academia



Google Cloud

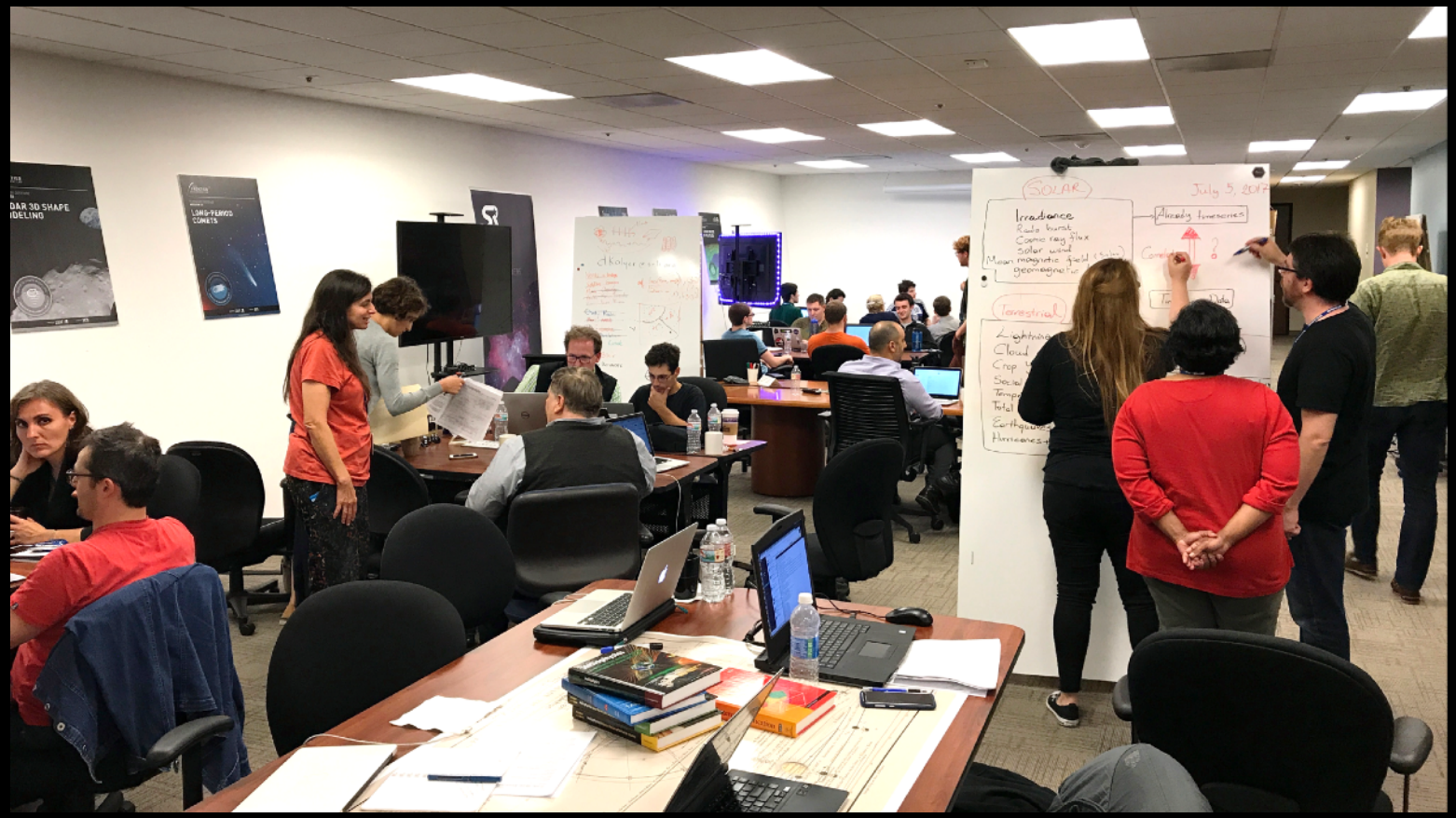
SETI INSTITUTE

NASA

UNIVERSITY OF OXFORD

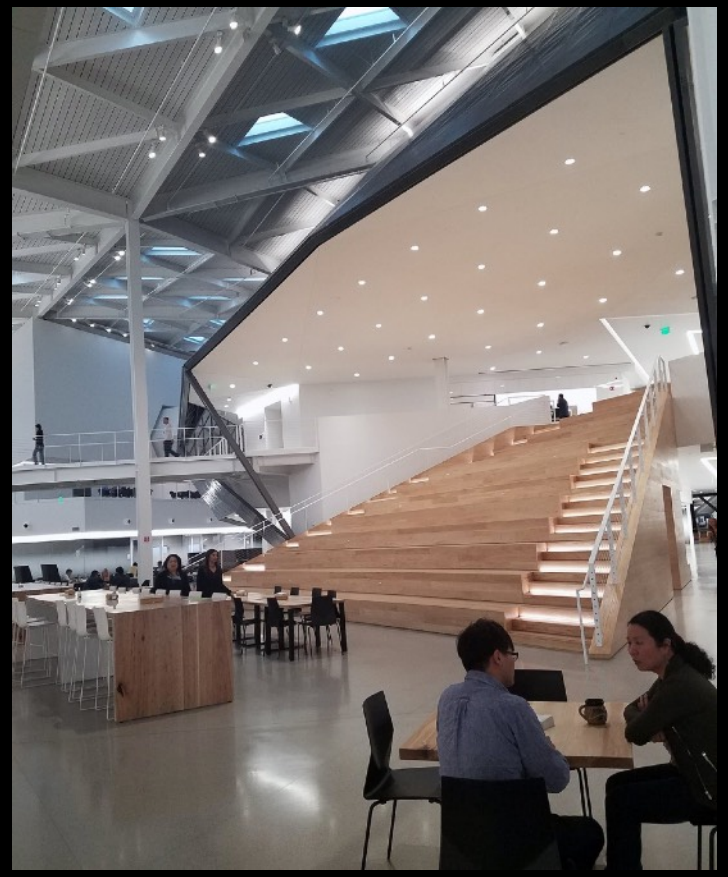
esa

What: 8-Week Summer Research Accelerator



Interdisciplinary teams leverage the latest GPU & CPU technology and advanced machine learning tools for an intensive summer workshop – supported by subject matter experts from Industry, NASA and the research community

When: Late June to Late August



Week 1: AI Boot camp at NVIDIA

Week 8: Team Presentations at Intel

Where: Mountain View, California

SETI INSTITUTE

NASA

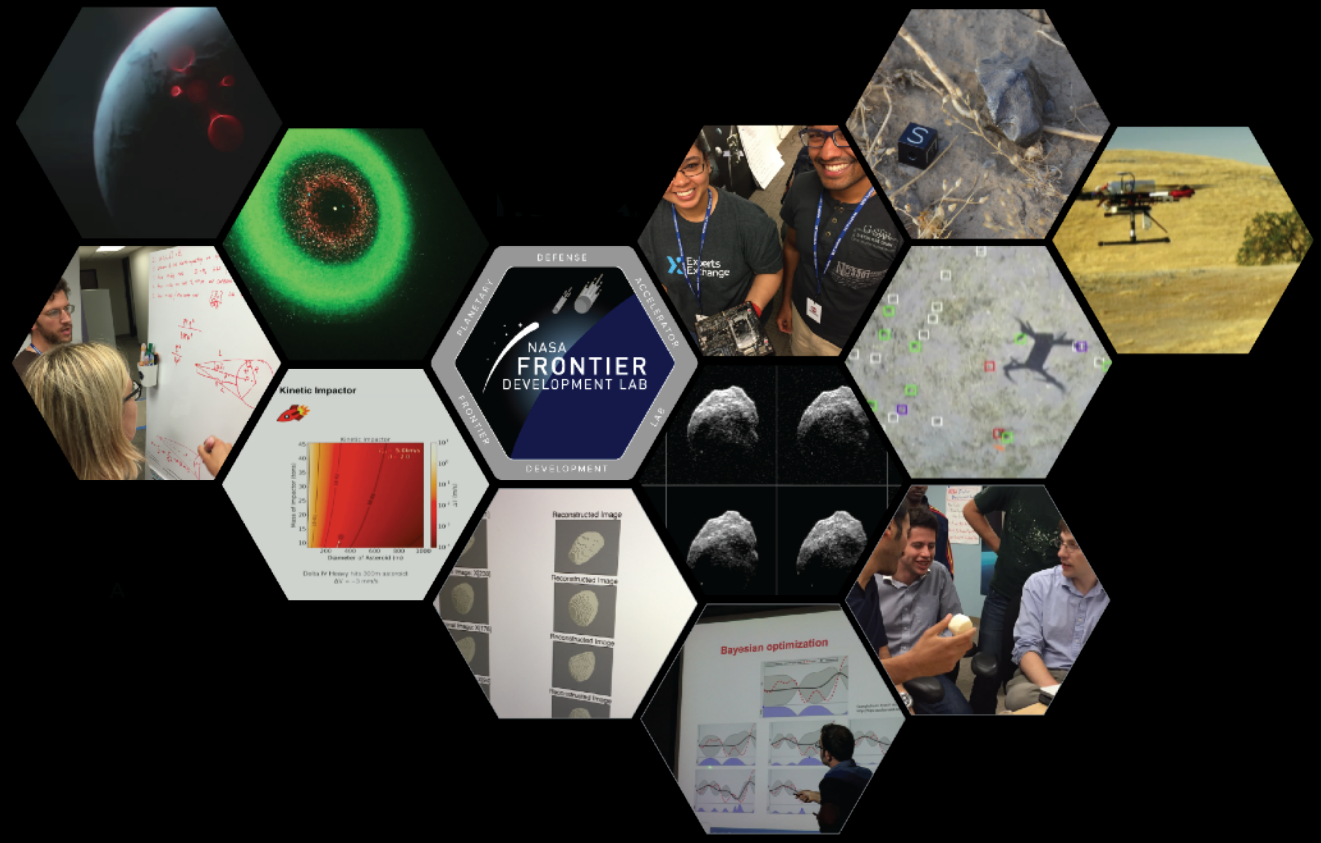
Why? To Accelerate Discovery & Understanding

Process Improvement:
3D asteroid shape modeling

Discovery:
Finding long-period comets

Understanding:
Forecasting solar behavior

Exploration:
Enabling autonomous navigation



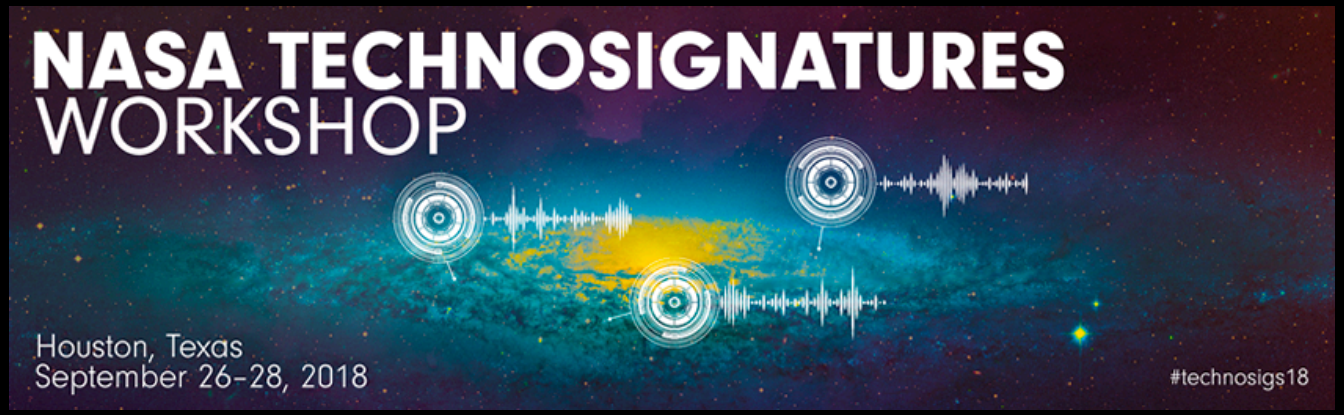
Pace of Data Generation Far Exceeds Pace of Data Analysis

Program History and Launch

SETI Institute engaged in 2015 to host & administer FDL due to:

- Institute history supporting NASA research and existing cooperative agreement
- Institute proximity to and relationships with NASA ARC
- Location in Silicon Valley – Key geographic center for AI/ML tools and technology
- Ability to engage private companies to explore partnership opportunities
- Science mentors to support initial FDL investigations into NEO’s and Planetary Defense


Grant Proposals



H. R. 4346
The CHIPS and Science Act of 2022

(5) TECHNOSIGNATURES.—In carrying out the program under paragraph (1), the Administrator may support, as appropriate, merit-reviewed, competitively selected research on technosignatures.

SUPERCLUSTER

NEXT LAUNCH: 00 D : 05 H : 11 M : 06 S

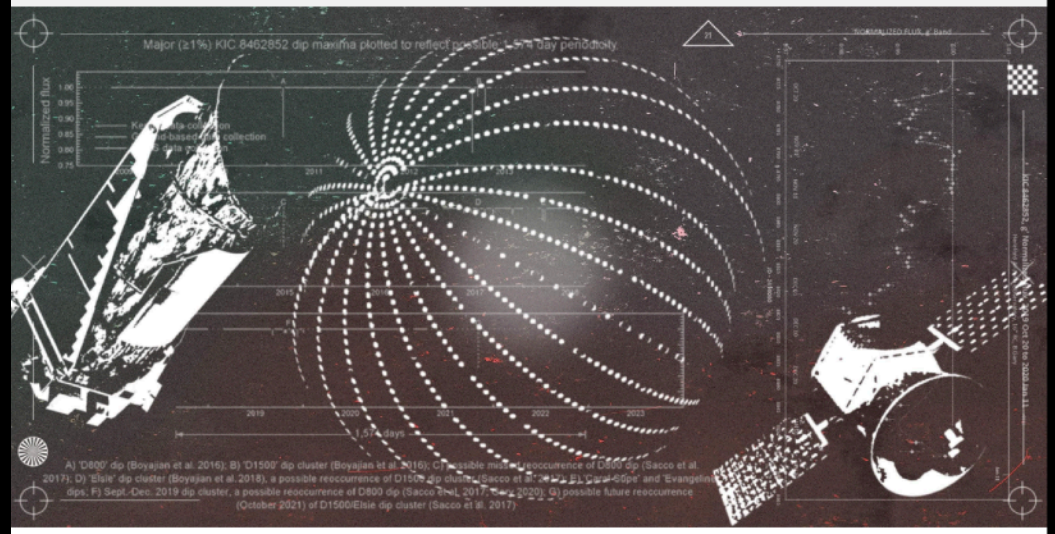
NASA IS SUPPORTING THE SEARCH FOR ALIEN MEGASTRUCTURES

SETI, NASA, BREAKTHROUGH LISTEN

DANIEL OBERHAUS
KAYLA DONLIN

SHARE

JULY 6, 2021 6:00 AM



There is something strange happening around Boyajian's star.

Something very strange. The Sun-sized star is located nearly 1,500 light years from Earth in the Cygnus constellation and in 2015, a team of astronomers and citizen scientists discovered irregular

Amateur Radio Digital Communications

Grant: GNU Radio Usability Enhancements

Date: March 2022
Amount: $263,011

GNU Radio is a free, open-source software-development toolkit that provides signal processing blocks to implement software radios. GNU Radio is always striving to be accessible to anyone across the globe, regardless of which operating system they are using and how much experience they have with wireless communications and digital signal processing. Historically, Windows operating system users have not had adequate support, despite it being the operating system used by nearly all K-12 students. Increasingly, macOS is becoming the platform of choice for both students and individuals. GNU Radio wants to be more intuitive and make it easier to install third-party modules known as out-of-tree modules (OOTs).

The GNU Radio project has identified a number of improvements to GNU Radio that it hopes will make GNU Radio easier to use, more accesible, and easier to maintain. These improvements are broken down into the following categories:

- Installation of GNU Radio and out-of-tree modules (OOTs)
- Documentation
- Ongoing software maintenance and support
- GNU Radio Companion (GRC)


Are we alone?
Let's Find Out Together!
• Technical development (e.g. ATA)
• Education with GNU Radio
• Frontier Development Lab
• Grants
• etc.