

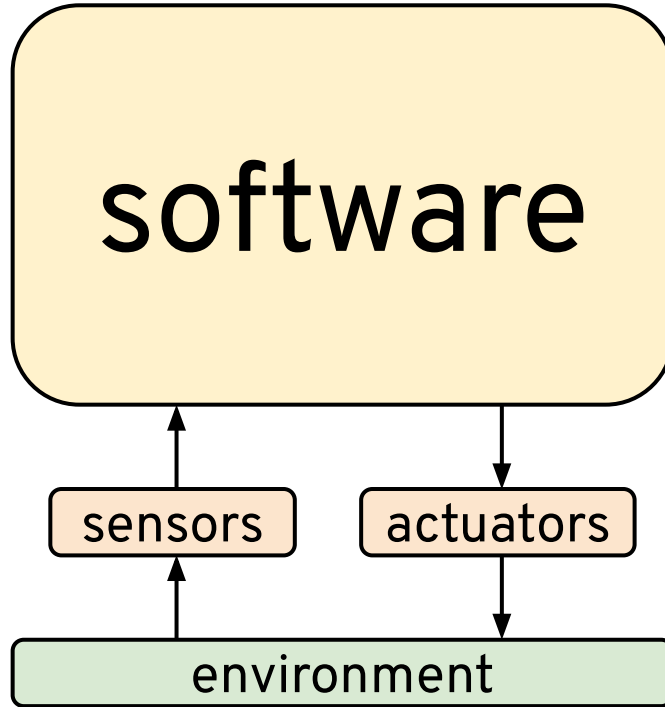


# Open source drives robotics ecosystems



# Robot software is hard

We need infrastructure to support experiments, build applications, and deploy solutions



# The (Bad) Old Days



# Academia

Researchers produced papers & videos, with little hope of reproducibility, much less reuse

How Robotics Research Keeps...

## Re-Inventing the Wheel

First, someone publishes...



...and they write code that barely works but lets them publish...



...a paper with a proof-of-concept robot.



This prompts another lab to try to build on this result...



But inevitably, time runs out...



...but they can't get any details on the software used to make it work...



...and countless sleepless nights are spent writing code from scratch.



So, a grandiose plan is formed to write a new software API...



...and all the code used by previous lab members is a mess.

# Government

R&D programs culminated in demos, quad charts, and reports; subsequent programs rarely leveraged prior results



# Industry

Commercial progress was slowed by reimplementation of basics and friction in using research results



# Can we get everyone working together?

HOW STANDARDS PROLIFERATE:  
(SEE: A/C CHARGERS, CHARACTER ENCODINGS, INSTANT MESSAGING, ETC.)

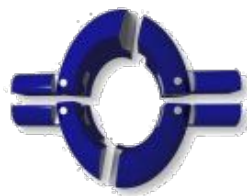


# Software reuse for robotics

Implement the common stuff once:

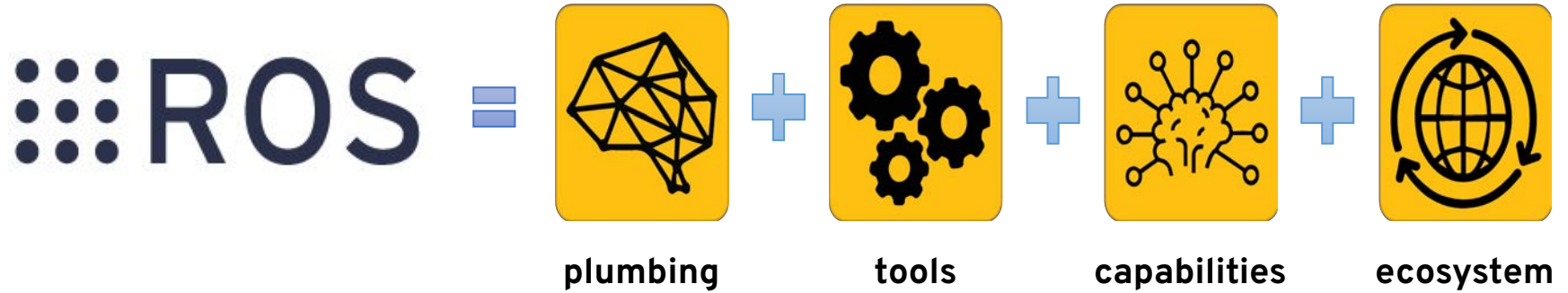
- message formats
- device drivers
- developer tools
- well-known algorithms

...and release it as open source code



*Open source robot frameworks ca. 2000-*





Permissive open source licensing  
(primarily Apache 2 or BSD) ensures  
compatibility with commerce

# THE ROS PRODUCT FAMILY

 ROS

**ROS**  
Full stack  
robotics SDK



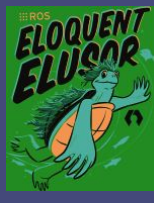
**Gazebo**  
Cloud-ready  
digital twin



**Open-RMF**  
Interoperable  
fleet management

# 15 years of ROS development

2022



2007





First commercially available **ROS-based** robot

2010



**ROS-based** humanoid robot helping astronauts on the International Space Station

2014



Singapore commits to **Open-RMF** for robot interoperability

2018

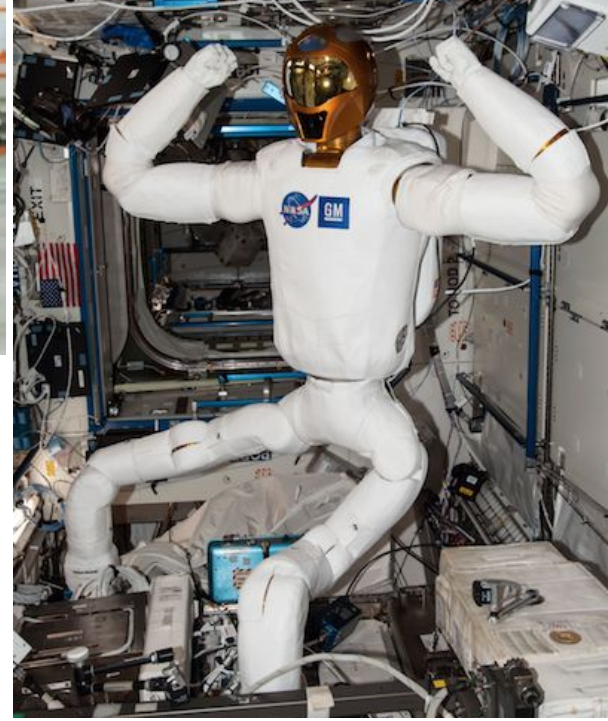


Automotive safety certification granted to **ROS-based** vehicle software system

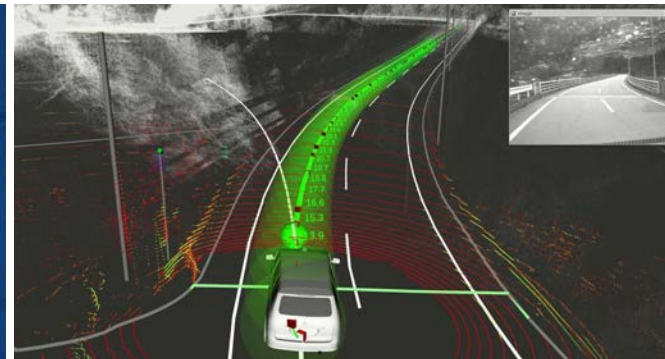
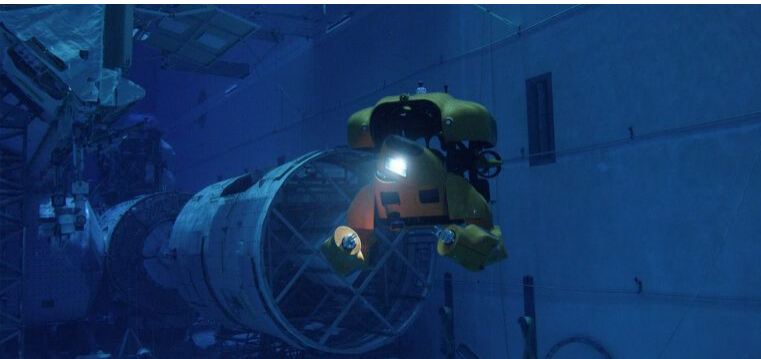


DARPA awards \$1.5M in prizes to winners of robot search-and-rescue competition running on **Gazebo** in the cloud

2021



**ROS robots are everywhere**



# ROS IN EVERY MARKET

## Aerospace



BLUE ORIGIN



ELROY AIR



## Agriculture



JOHN DEERE



## Automotive

cruise

Apex.AI



AUTOWARE.AI

## Consumer

Robot



aibo



## Delivery



CATERPILLAR

STARSHIP

ROBOTIS

## Logistics



LOCUS

OTTO  
MOTORS



Now Part of Zebra Technologies

# GLOBAL IMPACT

**2.2M**



ROS installs & updates  
per month

**>1.3K**



Contributors to ROS in 2021

**>\$4B**



Known  
acquisitions of  
ROS-based  
companies

**>150**



Organizations have  
sponsored ROSCon: Arm,  
Intel, BMW, Toyota, Google,  
Microsoft, and many more

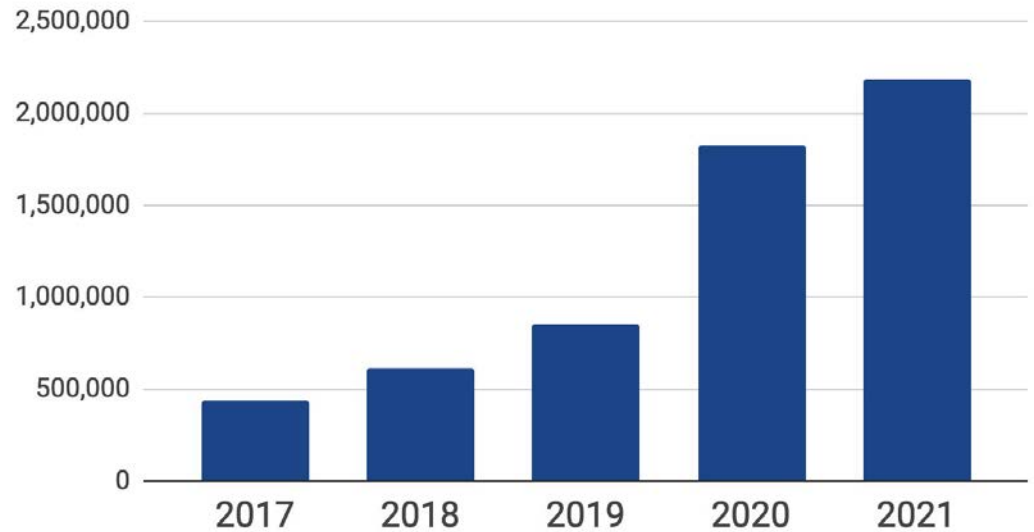
# We're at the center of the robotics industry

Monthly installs 2021: **2.2M**

CAGR 2017-21: **37.8%**

→ Estimated from [packages.ros.org](https://packages.ros.org) downloads and [wiki.ros.org](https://wiki.ros.org) visitors

Average monthly ROS installs & updates





# The open source community builds upon us

6K



Public GitHub repositories  
using the topic **ros**

1K



Public GitHub repositories  
using the topic **gazebo**

Reference points for GitHub topic use:



**android:** [96K](#) ([5.9M developers](#))



**arduino:** [25K](#) ([30M active community members](#))



**raspberry-pi:** [14K](#) ([38M units sold](#))

# We're a global robotics hub

Selected ROSCon  
sponsors 2012-2021



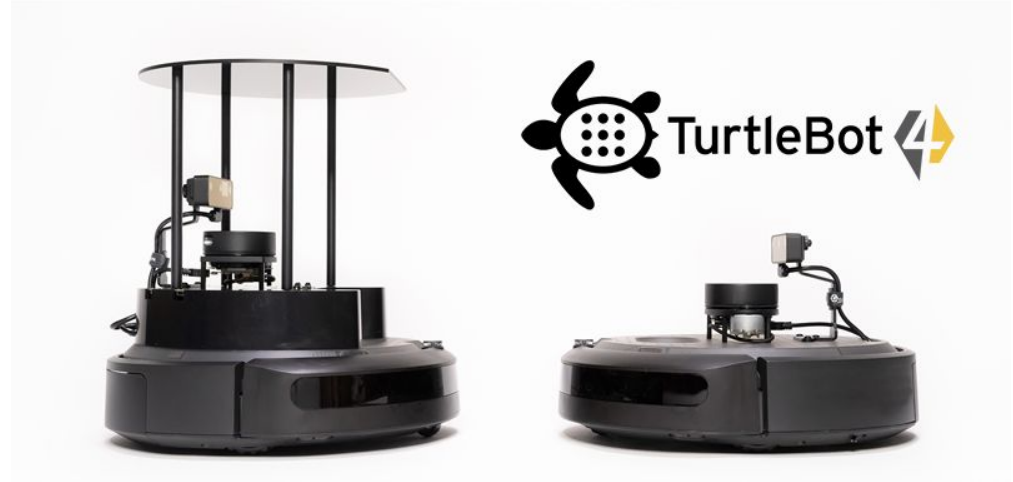
ALIAS ROBOTICS  
Robot Cybersecurity



LOCUS



# Modern Times



# Academia

Facilitated by ROS, GitHub, and other common resources, researchers commonly release code to accompany publications

<sup>4</sup>Our code is available at [https://github.com/wonderren/public\\_moes](https://github.com/wonderren/public_moes)

<sup>2</sup>The source code for our implementation of FMCW LiDAR is available in our fork of CARLA at <https://github.com/aevainc/carla>.

```
robotics-worldwide [software] ROSboard: Live-streamed visuals in your web browser (ROS1+ROS2) -- Sun, 18 Jul 2021 11:44:15 -0700
  dheera at dheera.net (Dheera Venkatraman)
robotics-worldwide [software] Code release: HDF5 to ROS bag converter for event camera data -- Wed, 14 Jul 2021 00:00:00
  guillermo.gallego at ifi.uzh.ch (Guillermo Gallego)
robotics-worldwide [software] MoveIt 2.2.0 Released for ROS 2 Galactic & Rolling -- Thu, 8 Jul 2021 14:01:29 -0700
  mark at picknik.ai (Mark Moll)
robotics-worldwide [software] Code release: EVO: Monocular Event-based VO/SLAM -- Thu, 8 Jul 2021 18:44:25 +0000
  scaramuzza.davide at gmail.com (Davide Scaramuzza)
robotics-worldwide [software] NVIDIA releasing Isaac SDK and Isaac Sim Open Beta -- Mon, 21 Jun 2021 17:49:03 +0000
  miteshp at nvidia.com (Mitesh Patel)
robotics-worldwide [software] Releasing code for Patch-NetVLAD (visual place recognition / loop closure) -- Mon, 21 Jun 2021 21:25:22 +0000
  tobias.fischer at qut.edu.au (Tobias Fischer)
robotics-worldwide [software] Code and Data release: Time Lens: Event-based Video Frame Interpolation -- Tue, 15 Jun 2021 17:10:06 +0200
  scaramuzza.davide at gmail.com (Davide Scaramuzza)
robotics-worldwide [software] Releasing VINSEval, an evaluation framework for unified comparison of VINS algorithms -- Wed, 2 Jun 2021 19:40:47 +0000
  stephan.weiss at aau.at (Weiss, Stephan Michael)
robotics-worldwide [software] Releasing Event-camera Calibration Toolbox -- Mon, 31 May 2021 19:32:03 +0200
  scaramuzza.davide at gmail.com (Davide Scaramuzza)
robotics-worldwide [software] ChoiRBot: a ROS 2 Toolbox for Cooperative Robotics -- Mon, 31 May 2021 18:27:16 +0000
  giuseppe.notarstefano at unibo.it (Giuseppe Notarstefano)
```

using the classic Nesterov acceleration scheme [29]. The code to run the benchmarks is made freely available at: <https://github.com/lmontaut/collision-detection-benchmark>.

respectively. Code, videos, and supplementary material can be found at <https://github.com/BerkeleyAutomation/FogROS>.

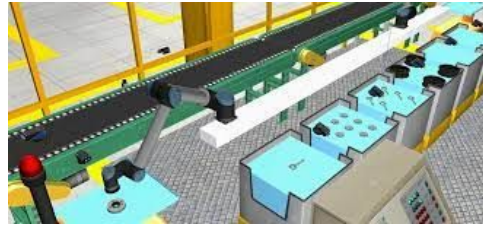
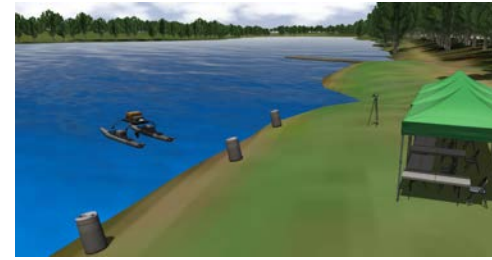
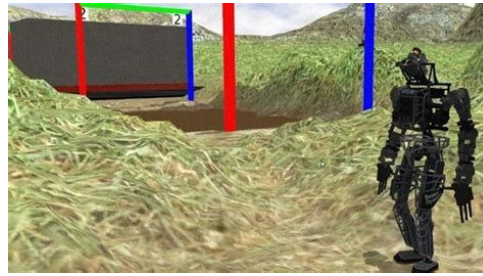
# A TECHNOLOGY PIPELINE

From Classroom to Research to Production



# Government

R&D programs build directly on earlier results and PMs expect software to be delivered in a reusable manner



*International robotics competitions using  
Gazebo 2013-2022*

## NASA's next lunar rover will run open-source software

The mission could turn the space industry on to less expensive, more accessible technologies.

By Neel V. Patel

April 12, 2021



Gazebo for design, development, and test

ROS for ground flight software

Scheduled to launch 2024

Inspiration for Space ROS

# Industry

An explosion in commercial progress is being driven by ROS and other open infrastructure

2018: MiR  
acquired  
by  
Teradyne  
@ \$272M



2019:  
6 River  
acquired  
by Shopify  
@ \$450M



2019: Canvas acquired  
by Amazon



2021:  
Fetch  
acquired  
by Zebra  
@ \$300M



2021:  
Locus  
valued  
@ \$1B





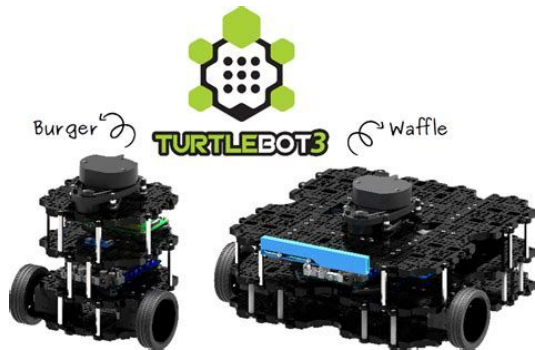


ROS-based AMRs

Gazebo for design, development, and test

Earliest commercial users of ROS





Education & research robots

~20K units sold

All running ROS with Gazebo support



ROBOTIS

ROBOTIS Official GitHub

📍 136 followers 📍 #37, Magok Jungang 5-ro 1-gil, Ga... <http://en.robotis.com/>

🏠 Overview 📁 Repositories 109 📁 Projects 📁 Packages 👤 People 6

Pinned

📁 **turtlebot3** Public

ROS packages for Turtlebot3

🐍 Python ☆ 1k 🍴 834

📁 **DynamixelSDK** Public

ROBOTIS Dynamixel SDK (Protocol1.0/2.0)

🟢 C# ☆ 349 🍴 308

📁 **OpenCR** Public

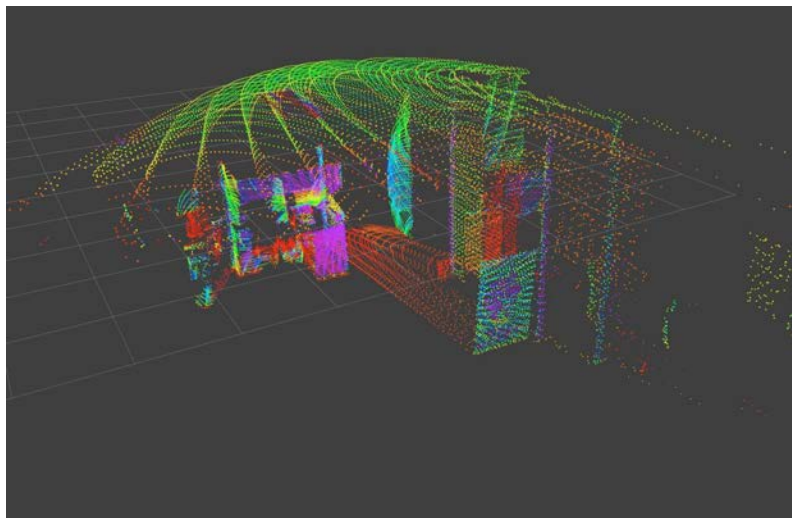
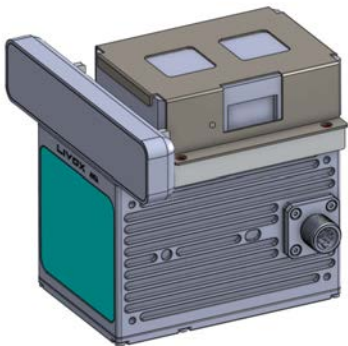
Software for ROS Embedded board (a.k.a. OpenCR). OpenCR means Open-source Control Module for ROS.

🟡 C ☆ 325 🍴 213

📁 **open\_manipulator** Public

OpenManipulator for controlling in Gazebo and Moveit with ROS

🔴 C++ ☆ 237 🍴 134



New delivery robot

Running ROS 2

Working with Open Robotics on hardware mockup and software development

# COMMON CONCERNS

- *ROS isn't ready for industry*
- *ROS isn't safe/safe OS is required to build robots*
- *ROS is too big/heavyweight*
- *ROS is too complicated*
- *ROS is open source, which means it's not secure*



# WHAT YOU CAN DO

## Academia

- Share your code when you publish
- Demand the same when you review

## Industry

- Set policy for open source use and contribution
- Provide open source SDKs for your products

## Government

- Prefer (or require) open source solutions
- Test & measure with open source systems

## Everyone

- Use ROS in your work and help us to improve it
- Be public about your use of ROS

# Join us!





**October 18th-20th, 2023!**

