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Q&A WITH SPEAKER [SPEAKER BIO](#)



Katherine Scott
Developer Advocate
Open Robotics

Katherine Scott is the developer advocate for Open Robo makers of Robot Operating System (ROS) and the Gazet platform. Katherine is the former analytics lead at Plane Strateos and was a co-founder of Tempo Automation an Machine. Katherine serves on the board of the Open Sou Association and holds degrees in electrical engineering, engineering from University of Michigan, and a masters science from Columbia University. My previous talks can here:

<https://github.com/kscottz/resume/blob/master/KatherineScott.pdf>
A less up to date list of projects can be found here:
<http://www.kscottz.com/>

VIDEO

The video player shows a presentation slide titled "ROS users aren't just researchers" by Open Robotics. The slide lists various statistics about ROS usage and includes a line graph from metrics.ros.org showing the growth of ROS users over time.

- 300+ companies*
 - Fortune 50
 - Small Startups
 - Everything in Between
- 264,000,000 deb downloads in 2019
- 35,000 QA Users
- ~5000 Forum Users
- ~2000+ Repos
- 200k Wiki Visits / Month
- ~7000 Research Citations

metrics.ros.org

ROS Metrics

Number of ROS Users

Number of ROS users (in thousands) from 2013 to 2019



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Activities Google Chrome Thu 18:13

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docs.google.com/presentation/d/1jy61570AC14n388uF8y9wvdr76gndm56TK2yy9Fv4dyQwQxTyleB3?slide=id.g65276a0f712_0_14

open robotics ROS2

In the before times...

Repetitive

Manufacturing & Research

Dull, Dirty, Dangerous

Science Fiction

Link to Product



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Software before times...

Proprietary

Works on Windows 95!

Hardware Controllers

Bespoke

"System Integrators"

Feed Forward

VENDORS

Speaker icon

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ros.google.com/present-at-jury/579AC114n388uF8yreswlrp9gndR6Q1K2yypCufdyQoxstyle83wIdr-id-g827heul732_8_14

open robotics ROS2

Then about 2004, things started happening...



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Then about 2004, things started happening...





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Three Really broad trends in late 2000's



Flexible Robots IPO \$\$\$ FOSS Communities "Web 2.0"



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open robotics ROS2

2007 Poof! Can we do FOSS but for robots?





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Three Projects are Born



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Activities Google Chrome Thu 18:18

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open robotics ROS2

Two Robots are Born



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open robotics ROS2

Willow: Shared World Class Research



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ethos.google.com/presentation/6182zyyq7v7dhyQox7hJed8#slide=id.g6125e6d7f12_8_14

open robotics ROS2

Ethos of Global Research Community

- Federation over Centralization
- Small, Simple, Composable Utilities
- Don't Reinvent the Wheel (shared common tools)
- Non-Exclusive (polyglot, packaging infrastructure)
- Inclusive (can be used *in addition to*, not in place of)
- Freedom (non-restrictive license)





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2013 Willow Folds but Open Source Lives On!



Willow Garage



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open robotics ROS2

The Spirit Lives On: OpenRobotics



Speaker: A woman in a blue shirt is visible in a small video window on the left. The main content is a Google Slides presentation titled 'The Spirit Lives On: OpenRobotics' featuring the Open Robotics and ROS industrial logos. The presentation is being viewed in a Google Chrome browser window. The video player interface includes a 'Take a Photo' button, a 'Present with Google Slides' button, and a URL bar showing the Google Docs link. The bottom of the video player shows a speaker icon and a settings icon.



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ros.google.com/present/.../g8s2houbf32_8_14

open robotics ROS2

~2018 ROS 2: Production ROS

Release	Release Date	Project	Future Release is Expected	Release Date
ROS 2.0.0	May 2018	ROS 2.0.0	Yes	May 2018
ROS 2.0.1	May 2018	ROS 2.0.1	Yes	May 2018
ROS 2.0.2	May 2018	ROS 2.0.2	Yes	May 2018
ROS 2.0.3	May 2018	ROS 2.0.3	Yes	May 2018
ROS 2.0.4	May 2018	ROS 2.0.4	Yes	May 2018
ROS 2.0.5	May 2018	ROS 2.0.5	Yes	May 2018
ROS 2.0.6	May 2018	ROS 2.0.6	Yes	May 2018
ROS 2.0.7	May 2018	ROS 2.0.7	Yes	May 2018
ROS 2.0.8	May 2018	ROS 2.0.8	Yes	May 2018
ROS 2.0.9	May 2018	ROS 2.0.9	Yes	May 2018
ROS 2.0.10	May 2018	ROS 2.0.10	Yes	May 2018
ROS 2.0.11	May 2018	ROS 2.0.11	Yes	May 2018
ROS 2.0.12	May 2018	ROS 2.0.12	Yes	May 2018
ROS 2.0.13	May 2018	ROS 2.0.13	Yes	May 2018
ROS 2.0.14	May 2018	ROS 2.0.14	Yes	May 2018
ROS 2.0.15	May 2018	ROS 2.0.15	Yes	May 2018
ROS 2.0.16	May 2018	ROS 2.0.16	Yes	May 2018
ROS 2.0.17	May 2018	ROS 2.0.17	Yes	May 2018
ROS 2.0.18	May 2018	ROS 2.0.18	Yes	May 2018
ROS 2.0.19	May 2018	ROS 2.0.19	Yes	May 2018
ROS 2.0.20	May 2018	ROS 2.0.20	Yes	May 2018
ROS 2.0.21	May 2018	ROS 2.0.21	Yes	May 2018
ROS 2.0.22	May 2018	ROS 2.0.22	Yes	May 2018
ROS 2.0.23	May 2018	ROS 2.0.23	Yes	May 2018
ROS 2.0.24	May 2018	ROS 2.0.24	Yes	May 2018
ROS 2.0.25	May 2018	ROS 2.0.25	Yes	May 2018
ROS 2.0.26	May 2018	ROS 2.0.26	Yes	May 2018
ROS 2.0.27	May 2018	ROS 2.0.27	Yes	May 2018
ROS 2.0.28	May 2018	ROS 2.0.28	Yes	May 2018
ROS 2.0.29	May 2018	ROS 2.0.29	Yes	May 2018
ROS 2.0.30	May 2018	ROS 2.0.30	Yes	May 2018
ROS 2.0.31	May 2018	ROS 2.0.31	Yes	May 2018
ROS 2.0.32	May 2018	ROS 2.0.32	Yes	May 2018
ROS 2.0.33	May 2018	ROS 2.0.33	Yes	May 2018
ROS 2.0.34	May 2018	ROS 2.0.34	Yes	May 2018
ROS 2.0.35	May 2018	ROS 2.0.35	Yes	May 2018
ROS 2.0.36	May 2018	ROS 2.0.36	Yes	May 2018
ROS 2.0.37	May 2018	ROS 2.0.37	Yes	May 2018
ROS 2.0.38	May 2018	ROS 2.0.38	Yes	May 2018
ROS 2.0.39	May 2018	ROS 2.0.39	Yes	May 2018
ROS 2.0.40	May 2018	ROS 2.0.40	Yes	May 2018
ROS 2.0.41	May 2018	ROS 2.0.41	Yes	May 2018
ROS 2.0.42	May 2018	ROS 2.0.42	Yes	May 2018
ROS 2.0.43	May 2018	ROS 2.0.43	Yes	May 2018
ROS 2.0.44	May 2018	ROS 2.0.44	Yes	May 2018
ROS 2.0.45	May 2018	ROS 2.0.45	Yes	May 2018
ROS 2.0.46	May 2018	ROS 2.0.46	Yes	May 2018
ROS 2.0.47	May 2018	ROS 2.0.47	Yes	May 2018
ROS 2.0.48	May 2018	ROS 2.0.48	Yes	May 2018
ROS 2.0.49	May 2018	ROS 2.0.49	Yes	May 2018
ROS 2.0.50	May 2018	ROS 2.0.50	Yes	May 2018
ROS 2.0.51	May 2018	ROS 2.0.51	Yes	May 2018
ROS 2.0.52	May 2018	ROS 2.0.52	Yes	May 2018
ROS 2.0.53	May 2018	ROS 2.0.53	Yes	May 2018
ROS 2.0.54	May 2018	ROS 2.0.54	Yes	May 2018
ROS 2.0.55	May 2018	ROS 2.0.55	Yes	May 2018
ROS 2.0.56	May 2018	ROS 2.0.56	Yes	May 2018
ROS 2.0.57	May 2018	ROS 2.0.57	Yes	May 2018
ROS 2.0.58	May 2018	ROS 2.0.58	Yes	May 2018
ROS 2.0.59	May 2018	ROS 2.0.59	Yes	May 2018
ROS 2.0.60	May 2018	ROS 2.0.60	Yes	May 2018
ROS 2.0.61	May 2018	ROS 2.0.61	Yes	May 2018
ROS 2.0.62	May 2018	ROS 2.0.62	Yes	May 2018
ROS 2.0.63	May 2018	ROS 2.0.63	Yes	May 2018
ROS 2.0.64	May 2018	ROS 2.0.64	Yes	May 2018
ROS 2.0.65	May 2018	ROS 2.0.65	Yes	May 2018
ROS 2.0.66	May 2018	ROS 2.0.66	Yes	May 2018
ROS 2.0.67	May 2018	ROS 2.0.67	Yes	May 2018
ROS 2.0.68	May 2018	ROS 2.0.68	Yes	May 2018
ROS 2.0.69	May 2018	ROS 2.0.69	Yes	May 2018
ROS 2.0.70	May 2018	ROS 2.0.70	Yes	May 2018
ROS 2.0.71	May 2018	ROS 2.0.71	Yes	May 2018
ROS 2.0.72	May 2018	ROS 2.0.72	Yes	May 2018
ROS 2.0.73	May 2018	ROS 2.0.73	Yes	May 2018
ROS 2.0.74	May 2018	ROS 2.0.74	Yes	May 2018
ROS 2.0.75	May 2018	ROS 2.0.75	Yes	May 2018
ROS 2.0.76	May 2018	ROS 2.0.76	Yes	May 2018
ROS 2.0.77	May 2018	ROS 2.0.77	Yes	May 2018
ROS 2.0.78	May 2018	ROS 2.0.78	Yes	May 2018
ROS 2.0.79	May 2018	ROS 2.0.79	Yes	May 2018
ROS 2.0.80	May 2018	ROS 2.0.80	Yes	May 2018
ROS 2.0.81	May 2018	ROS 2.0.81	Yes	May 2018
ROS 2.0.82	May 2018	ROS 2.0.82	Yes	May 2018
ROS 2.0.83	May 2018	ROS 2.0.83	Yes	May 2018
ROS 2.0.84	May 2018	ROS 2.0.84	Yes	May 2018
ROS 2.0.85	May 2018	ROS 2.0.85	Yes	May 2018
ROS 2.0.86	May 2018	ROS 2.0.86	Yes	May 2018
ROS 2.0.87	May 2018	ROS 2.0.87	Yes	May 2018
ROS 2.0.88	May 2018	ROS 2.0.88	Yes	May 2018
ROS 2.0.89	May 2018	ROS 2.0.89	Yes	May 2018
ROS 2.0.90	May 2018	ROS 2.0.90	Yes	May 2018
ROS 2.0.91	May 2018	ROS 2.0.91	Yes	May 2018
ROS 2.0.92	May 2018	ROS 2.0.92	Yes	May 2018
ROS 2.0.93	May 2018	ROS 2.0.93	Yes	May 2018
ROS 2.0.94	May 2018	ROS 2.0.94	Yes	May 2018
ROS 2.0.95	May 2018	ROS 2.0.95	Yes	May 2018
ROS 2.0.96	May 2018	ROS 2.0.96	Yes	May 2018
ROS 2.0.97	May 2018	ROS 2.0.97	Yes	May 2018
ROS 2.0.98	May 2018	ROS 2.0.98	Yes	May 2018
ROS 2.0.99	May 2018	ROS 2.0.99	Yes	May 2018
ROS 2.0.100	May 2018	ROS 2.0.100	Yes	May 2018



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The screenshot shows a video player interface. At the top, there's a 'Take a Photo' button and a large image of a cat's face. Below that, a smaller video window shows a person speaking. The main content area displays a presentation slide from 'open robotics' titled 'Let's Talk about ROS Philosophy'. The slide lists several principles of ROS philosophy, including 'Don't Reinvent the Wheel', 'Federation over Centralization', 'Small, Simple, Composable Utilities', 'Non-Exclusive', 'Inclusive', and 'Freedom'. To the right of the list is a code block containing a list of guidelines in a similar style to the Zen of Python.

open robotics ROS2

Let's Talk about ROS Philosophy

- Don't Reinvent the Wheel
 - Shared common tools
- Federation over Centralization
- Small, Simple, Composable Utilities
- Non-Exclusive
- Inclusive
 - *In addition to, not in place of.*
- Freedom
 - non-restrictive license

```
See import this
The Zen of Python, by Tim Peters

Beautiful is better than ugly.
Explicit is better than implicit.
Simple is better than complex.
Complex is better than complicated.
Flat is better than nested.
Sparse is better than dense.
Readability counts.
Special cases aren't special enough to break the rules.
Although practicality beats purity.
Errors should never pass silently.
Unless explicitly silenced.
In the face of ambiguity, refuse the temptation to guess.
There should be one-- and preferably only one --obvious way to do it.
Although that way may not be obvious at first unless you're Dutch.
Now is better than never.
Although never is often better than "right" now.
If the implementation is hard to explain, it's a bad idea.
If the implementation is easy to explain, it may be a good idea.
Namespaces are one happy grokking idea -- let's do more of those!
```



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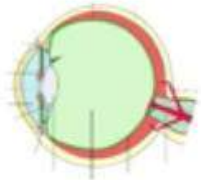
DefinitiveROS2Primer Present with Google Slides

Link to Product

open robotics ROS2

Don't Reinvent The _ _ _ _ _

- Let's look at some of the "wheels" in ROS 2
- Robots traditionally have three key parts:
 - Sensors, which take in data.
 - Actuators, which change the world.
 - Control, convert data to actions.

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open robotics ROS2

Don't Reinvent: Multiprocess Control

- ROS *nodes* are process encapsulation between languages.
- Compile, install, start, stop, pause, query status, and collect CLI arguments.
- Unlimited number of processes, in a bunch of *languages* across *packages*.

ACTUATOR

SENSOR

CONTROL



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open robotics ROS2

Don't Reinvent: Multiprocess Control

- IMAGINE:
 - C++ / Python programs that all start concurrently.
 - With hardware
 - And lots of configurable params
 - And control flow based on config
- What would your shell script file look like?

ACTUATOR

CONTROL

SENSOR

ROS nodes and launch files take care of this!



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open robotics ROS2

Don't Reinvent: Topics

- ROS *nodes* communicate over *topics*.
- Cross language serialization primitives that predate protobuf, rabbitMQ, etc.
- **STANDARD** message types for interop.
- Decades of tooling on top of this protocol.

```
graph LR; S[SENSOR] -- "/images/" --> C[CONTROL]; C -- "/hand_position/" --> S; C -- "/joint_positions/" --> A[ACTUATOR]; A -- "/feedback/" --> C
```

The diagram illustrates a robotic hand system. It features three main components: a **SENSOR** (represented by a green oval and a camera icon), a **CONTROL** unit (represented by a purple oval and a brain icon), and an **ACTUATOR** (represented by an orange oval and a hand icon). The communication flow is as follows: the **SENSOR** sends `/images/` to the **CONTROL** unit; the **CONTROL** unit sends `/hand_position/` back to the **SENSOR**; the **CONTROL** unit sends `/joint_positions/` to the **ACTUATOR**; and the **ACTUATOR** sends `/feedback/` back to the **CONTROL** unit.



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open robotics ROS2

Don't Reinvent: Topics

- Standard messages allow
 - Plug and play!
 - Loose coupling!
- Online introspection
- Quality of Service capabilities.
- Built as an abstraction. DDS implementation ensures security, robustness.

```
graph LR; S[SENSOR] -- "/images/" --> C[CONTROL]; C -- "/joint_positions/" --> A[ACTUATOR]; A -- "/feedback/" --> C; M[Monitor] -.-> "/images/";
```

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The video player shows a presentation slide from the ROS2 community. The slide is titled "Don't Reinvent: RVIZ" and features the Open Robotics logo in the top left and the ROS2 logo in the top right. The slide content includes a bulleted list:

- Robots make lots of data!
 - Much of it is live!
 - With 3D context!
 - Annotation!
- RVIZ is your GUI.

Below the text, there are four small images illustrating RVIZ capabilities: a 3D point cloud of a robot, a 3D model of a robot in a simulated environment, a 2D top-down view of a robot in a hallway, and a 3D view of a robot in a simulated environment. The video player interface includes a "Take a Photo" button in the top left, a "Present with Google Slides" button in the top center, and a "Link to Product" button in the top right. The video player also has a volume icon in the bottom left and a settings icon in the bottom right.



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Back google.com/presentations/19C1kn30bUfBpwwdMgqzWm61kEgpcv7m7QvzUwWtUwIdw-08_gnd7wvW72_8_14

open robotics

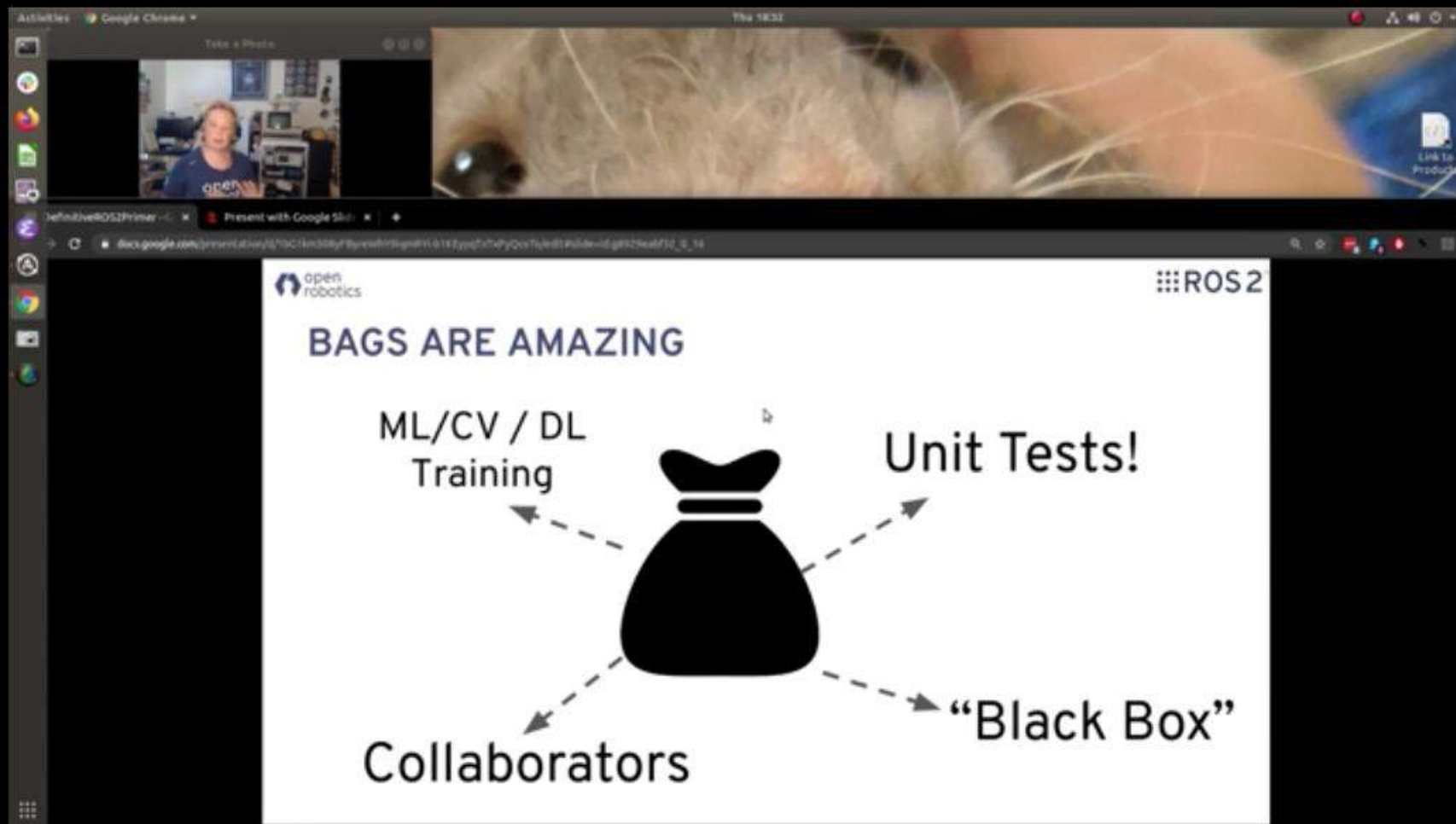
ROS2

Don't Reinvent: Bags

- Standard serialization library for transport also works for disk storage.
- We call it a "bag"!
- Great for
 - Machine Learning
 - Logging
 - Debug / Failure Analysis

The diagram illustrates a robotic system architecture. On the left, a camera icon is connected to a green oval labeled 'SENSOR'. A dashed arrow labeled '/images/' points from the sensor to a purple oval labeled 'CONTROL', which is accompanied by a brain icon. Below the control unit is a black bag icon, with a dashed arrow labeled '/joint_positions/' pointing from the control unit to it. To the right of the control unit is an orange oval labeled 'ACTUATOR', with a dashed arrow labeled '/joint_positions/' pointing from the control unit to it. A dashed arrow labeled '/feedback/' points from the actuator back to the control unit. At the top of the slide, there is a video feed of a person and a close-up image of a robotic eye.

VIDEO



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Don't Reinvent: Services / Actions

- Services: synchronous behavior API
- Actions: async behavior API
 - Handles request negotiation
 - With preemption
 - With status callbacks
- Callback driven API
- Build robust behaviors, *fast*.

Pick up red ball



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Activities Google Chrome Thu 18:36

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docs.google.com/presentation/d/1y5j279AC11n338yF8yresd0r6gdm0Q14Zyyd7v0dyQw0xhYd81wUde-ld_g8t2heulF12_8_14

open robotics ROS2

Don't Reinvent: Geometry / Kinematics

- *Hard robot problems*
 - Where is everything?
 - Where am I?
 - How to get from A to B?
 - I can see X, how to grasp it?
 - Many more!

ACTUATOR

SENSOR

CONTROL



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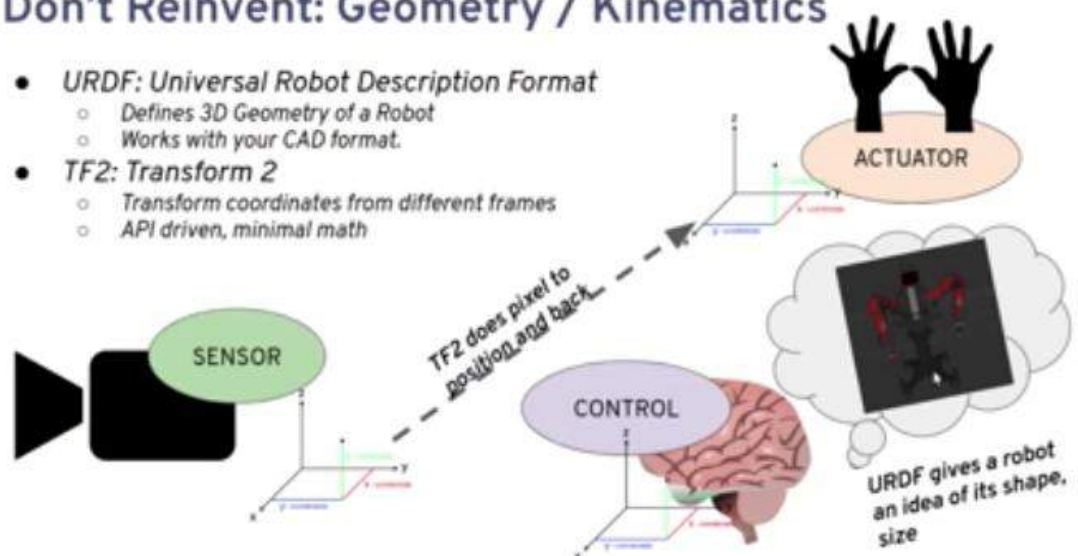
DefinitiveROS2Primer Present with Google Slides

ros.google.com/present-at-jy9t570AC1h308uF8y.../edit#slide=id.g65279e4d732_8_14

open robotics ROS2

Don't Reinvent: Geometry / Kinematics

- **URDF: Universal Robot Description Format**
 - Defines 3D Geometry of a Robot
 - Works with your CAD format.
- **TF2: Transform 2**
 - Transform coordinates from different frames
 - API driven, minimal math



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TF2 does pixel to position and back

URDF gives a robot an idea of its shape, size





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open robotics ROS2

Don't Reinvent: SLAM / Navigation

ROS Navigation

Overview

The navigation 2 package is the official successor to the ROS Navigation 1 package. It is a new package that is designed to be a drop-in replacement for the ROS Navigation 1 package. It is designed to be a drop-in replacement for the ROS Navigation 1 package. It is designed to be a drop-in replacement for the ROS Navigation 1 package.

Key features:

- ROS 2 ready, and more (like ROS 1)
- Better than ROS 1 (like ROS 1)
- More powerful than ROS 1 (like ROS 1)



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open robotics ROS2

Don't Reinvent: Simulation

- Robots are expensive, dangerous, slow.
- Sharing a robot is hard!
- Testing is hard.
- What if you didn't need a robot?
- What if you could have a robot VM?

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THE LINUX FOUNDATION
OPEN SOURCE SUMMIT
NORTH AMERICA



**Embedded Linux
Conference**
North America

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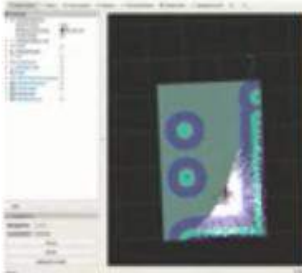


DefinitiveROS2Primer Present with Google Slides

ros.google.com/present-at-jury12/19c11n33b9f8yuewdrbqndm41k2yyp7vtdhyQwFyldB1kudevndg8t2heaf712_8_14

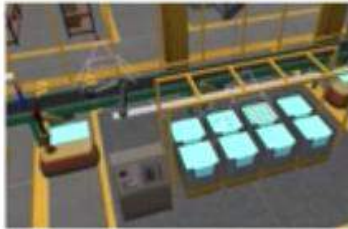
open robotics ROS2

Don't Reinvent: Simulation

- Ignition Gazebo, build a virtual robot
- Simulate Physics, robots, and sensors
- Plays well with ROS 2
- Allows you build, test, and debug from the comfort of your desk.

GAZEBO





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ROS Packages: Batteries Included

- ROS has a concept of packages.
 - Collections of code, that can be combined
- C++, Python, and many others!
- ROS federation means we need a multi-repo, multilingual meta build tool: Colcon
- Analogous to PIP / Python Wheels





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The screenshot shows a video player interface. At the top, there's a small video thumbnail of a person. Below it, the main video frame displays a presentation slide. The slide has the 'open robotics' logo in the top left and 'ROS2' in the top right. The title is 'ROS: Getting to Plug and Play Hardware'. The slide content includes several images: a robotic arm, a camera module, a sensor unit, and a list of ROS2 packages. The video player's address bar shows a Google Chrome window with a Google Slides presentation link.



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open robotics

ROS2

ROS 2: Hardware Ready

Bridge between ROS 2 DDS layer and an RTOS

Currently on NuttX but more in the works!

micro-ROS

puts ROS 2 onto microcontrollers

ROS

Watch Video

Getting Started

Get Involved

Join Micro-ROS on Slack

What's your email address?

GET IT NOW





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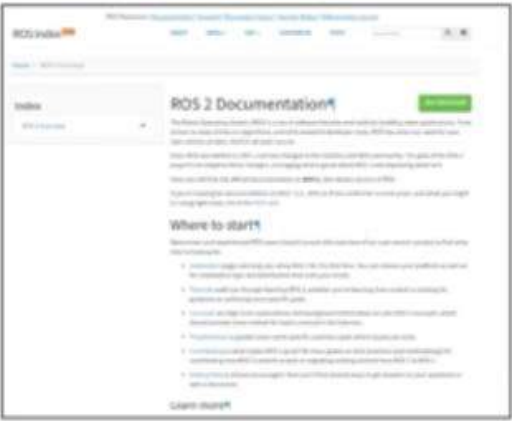
https://docs.google.com/presentation/d/1y5j373C11n338uF8y9wv8r8gpmY16TK3yp9vUyQxQxHw8d3w0de-ndg8t2h0u0732_8_34

open robotics ROS2

Community not just Code



ros.org



index.ros.org/doc/ros2/





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discourse.googleusercontent.com

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discourse.ros.org

answers.ros.org



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open robotics ROS2

ROS 2 Foxy

- Foxy Fitzroy is 6th ROS 2 Release.
- First major LTS
- Start now: three years of patches and support
- Upgrading is easy, H release is 5 years.



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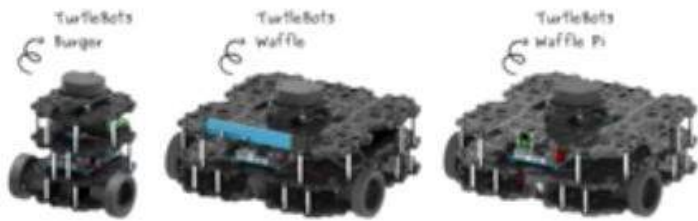
open robotics ROS2

I want to learn!

- DARPA SubT Simulator has great tutorials!
 - https://github.com/osrf/subt_hello_world
- Autoware Has Autonomy Class
 - <https://www.autoware.org/awf-course>
- ROS 2 Docs
 - index.ros.org/doc/ros2/

 **TURTLEBOT3**

TurtleBot3 Burger TurtleBot3 Waffle TurtleBot3 Waffle Pi

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The screenshot shows a Google Slides presentation titled "Definitive ROS2 Primer" being presented with Google Slides. The slide content includes the Open Robotics logo, the ROS2 logo, and a "THANKS!" message with the following text: @openroboticsorg, @rosorg, @kscottz, and ros.org. The presentation is viewed within a Google Chrome browser window on a Linux desktop environment. In the top left corner of the video frame, there is a small inset video of a person with blonde hair wearing a headset. The desktop background features a close-up image of a cat's face.



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Q&A WITH SPEAKER [SPEAKER BIO](#)

The slides are not clear. Could anything be done?

Should I start with ROS 1 or just completely dive in with ROS 2? Great talk!

ROS 2

Enter question here...

NEW QUESTION

VIDEO

