U.S. ARMY TANK AUTOMOTIVE RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

Introduction to Robotic Technology Kernel (RTK)

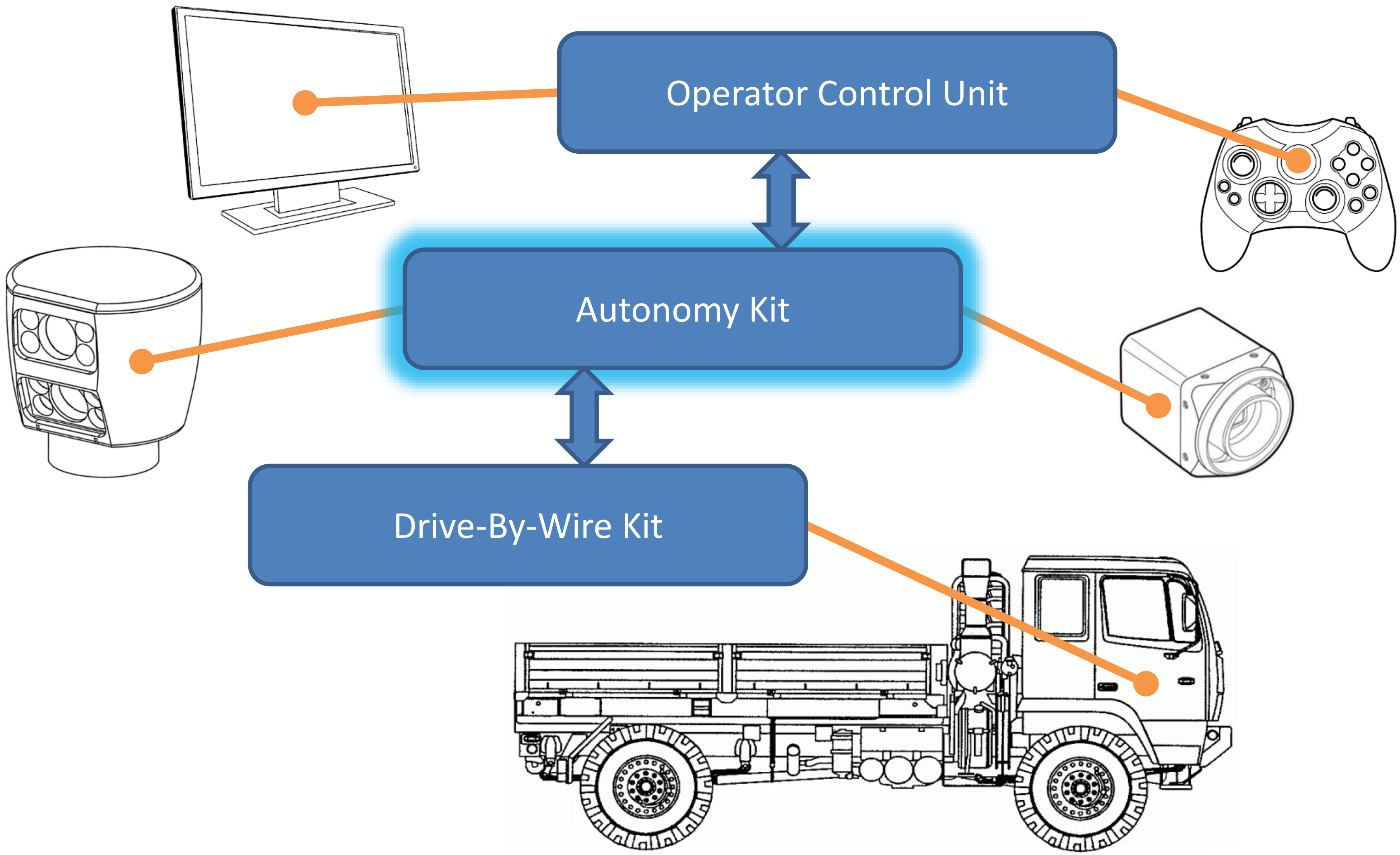
TARDEC Ground Vehicle Robotics

Presentation Overview

- RTK Overview
- Architecture
- Vehicle Configuration
- Development
- Useful Tools

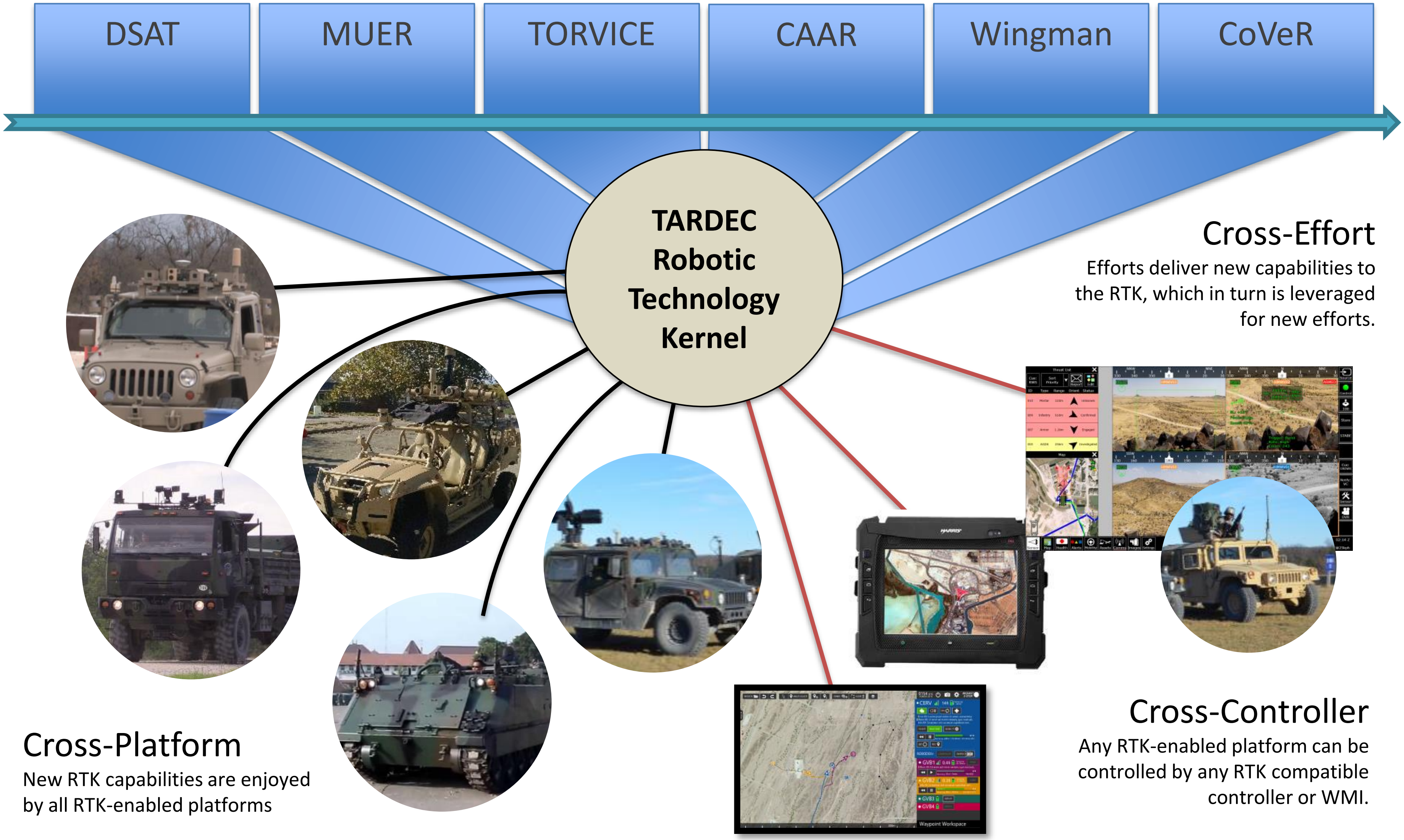
RTK Overview

Autonomy Kit/Drive-by-Wire Kit Concept



Robotic Technology Kernel (RTK)

The Robotic Technology Kernel (RTK) is a Robot Operating System (ROS)-based modular autonomy software library for S&T development that provides a set of common robotic capabilities across a variety of platforms and efforts.



Cross-Effort

Efforts deliver new capabilities to the RTK, which in turn is leveraged for new efforts.

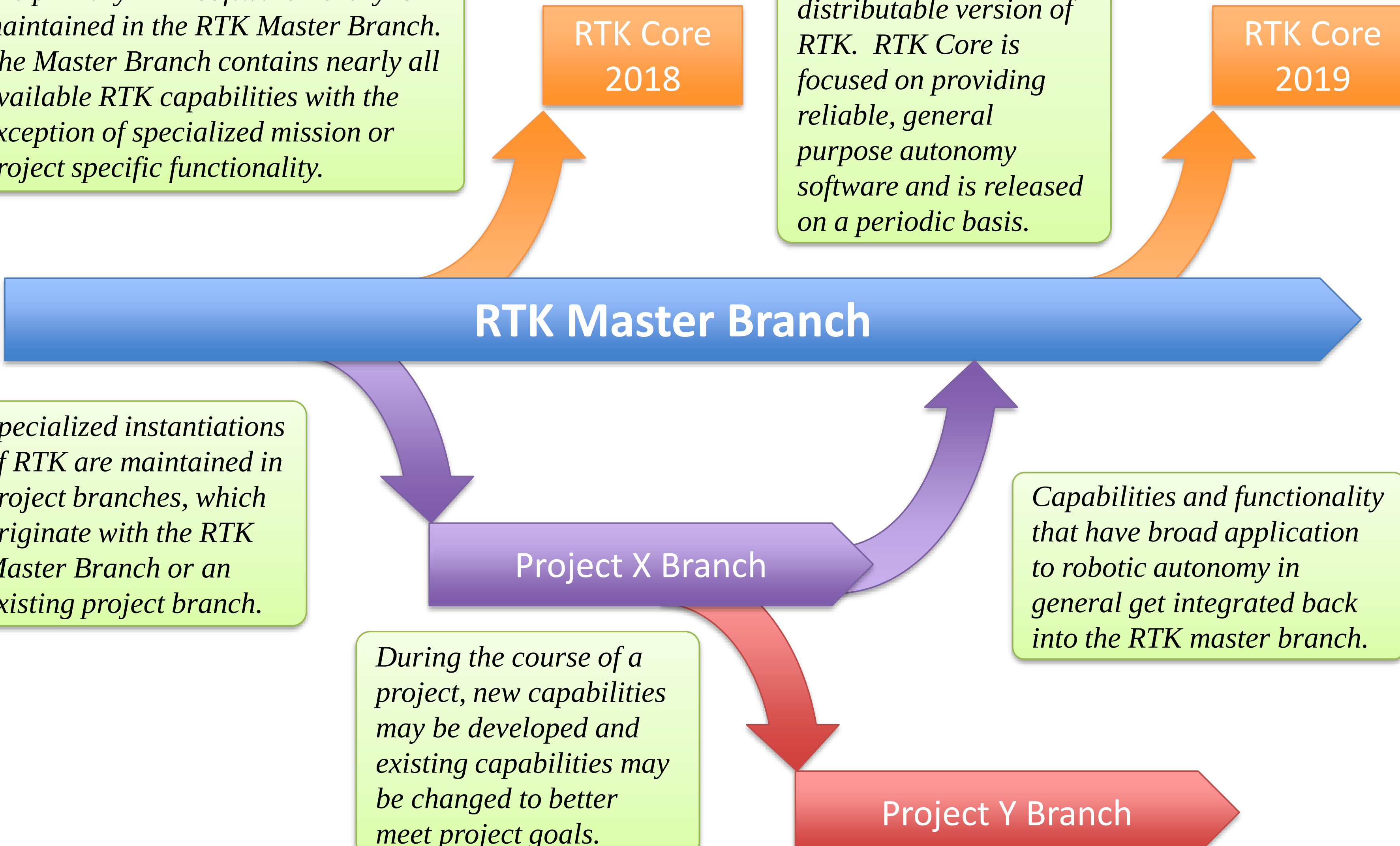
Cross-Platform

New RTK capabilities are enjoyed by all RTK-enabled platforms

Cross-Controller

Any RTK-enabled platform can be controlled by any RTK compatible controller or WMI.

RTK Software Development Concept



The primary RTK software library is maintained in the RTK Master Branch. The Master Branch contains nearly all available RTK capabilities with the exception of specialized mission or project specific functionality.

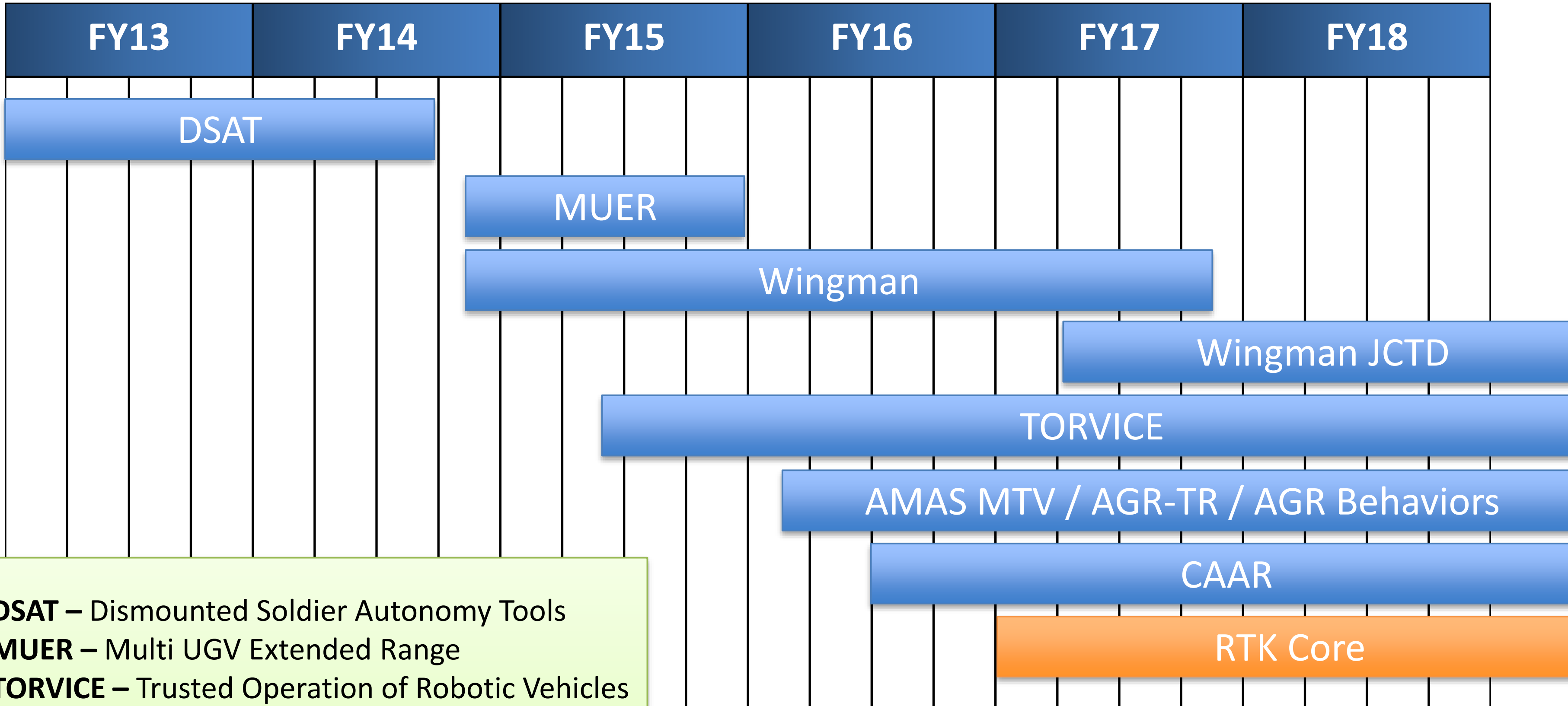
RTK Core is a documented and distributable version of RTK. RTK Core is focused on providing reliable, general purpose autonomy software and is released on a periodic basis.

Specialized instantiations of RTK are maintained in project branches, which originate with the RTK Master Branch or an existing project branch.

During the course of a project, new capabilities may be developed and existing capabilities may be changed to better meet project goals.

Capabilities and functionality that have broad application to robotic autonomy in general get integrated back into the RTK master branch.

RTK Past and Present

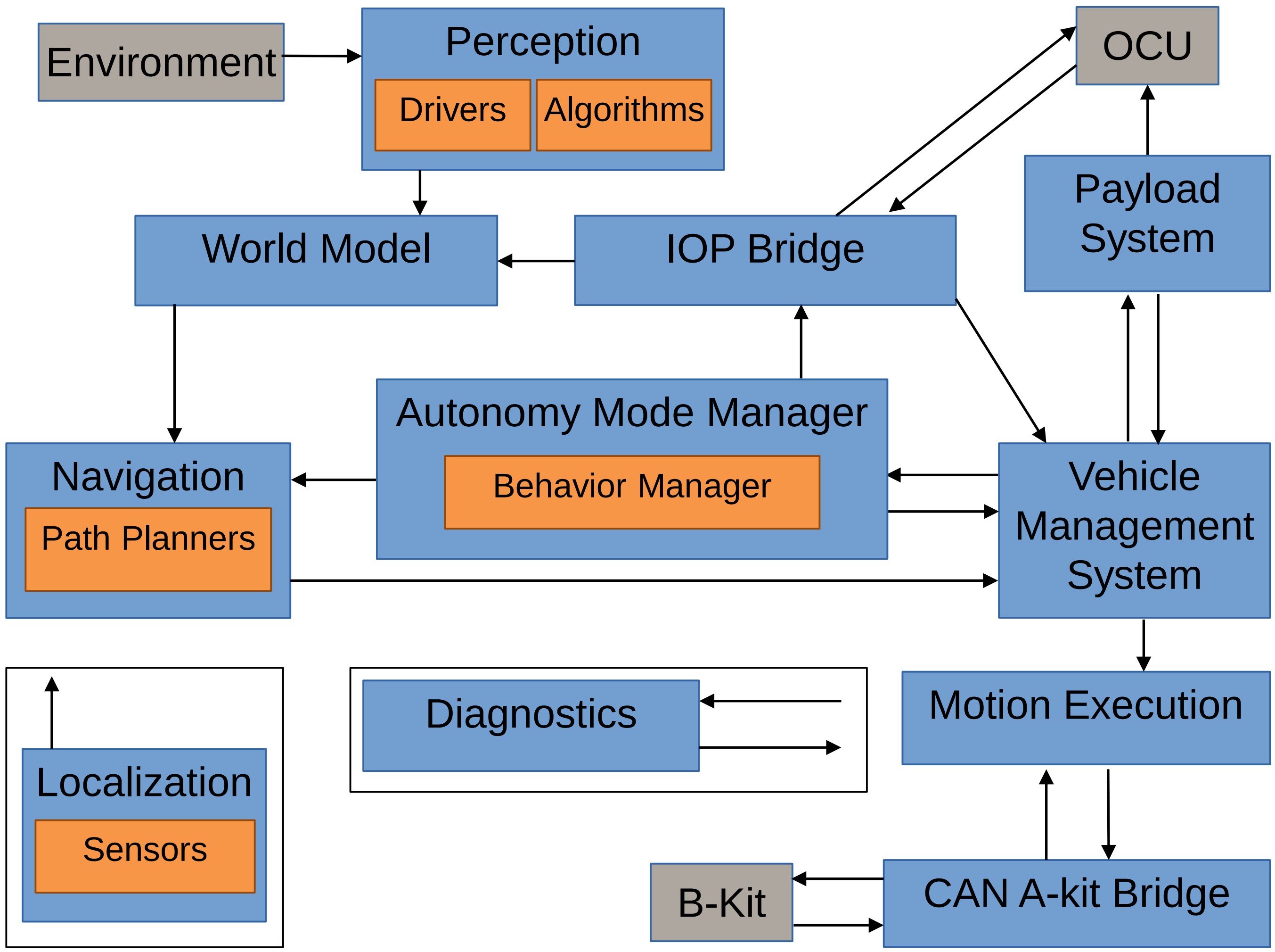


DSAT – Dismounted Soldier Autonomy Tools
MUER – Multi UGV Extended Range
TORVICE – Trusted Operation of Robotic Vehicles in a Contested Environment
AMAS – Autonomous Mobility Applique Kit
AGR – Autonomous Ground Resupply
TR – Tactical Resupply
CAAR – Coalition Assured Autonomous Resupply

In addition to the development efforts listed here, RTK has been and continues to be used on several other projects to provide autonomous capability.

Architecture

Data Flow

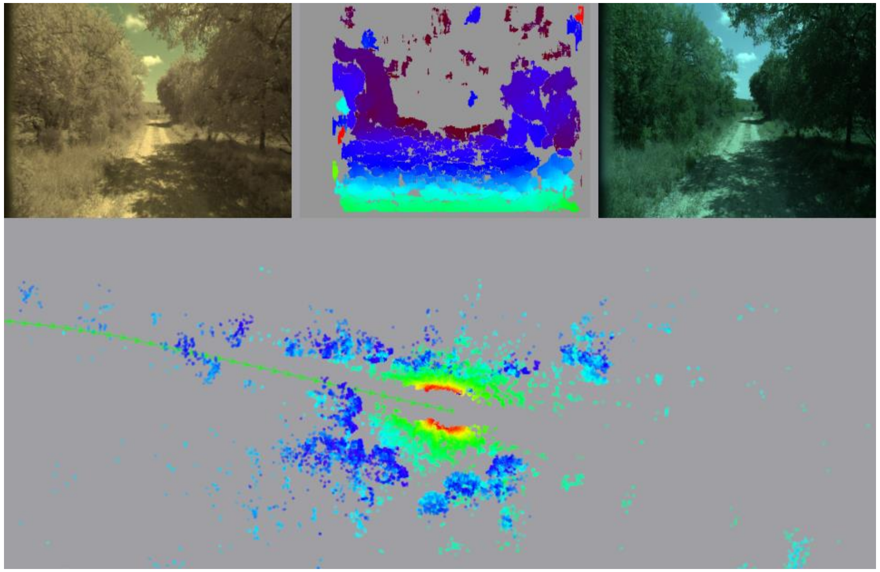

Environment
Perception
Drivers
Algorithms
OCU
Payload System
World Model
IOP Bridge
Autonomy Mode Manager
Behavior Manager
Navigation
Path Planners
Vehicle Management System
Localization
Sensors
Diagnostics
Motion Execution
B-Kit
CAN A-kit Bridge

Perception

This subsystem contains the sensor drivers and algorithms that detect and interpret things of interest from the environment.

- Stereo Cameras
- LIDARs
- Ultra Wideband Radios (UWBs)
- RADAR

- Output:
  - Disparity
  - Material Classification
  - Ground Point Clouds
  - Non-Ground Point Clouds



Localization

This subsystem fuses data from multiple sensors to provide both relative and absolute pose of the vehicle.

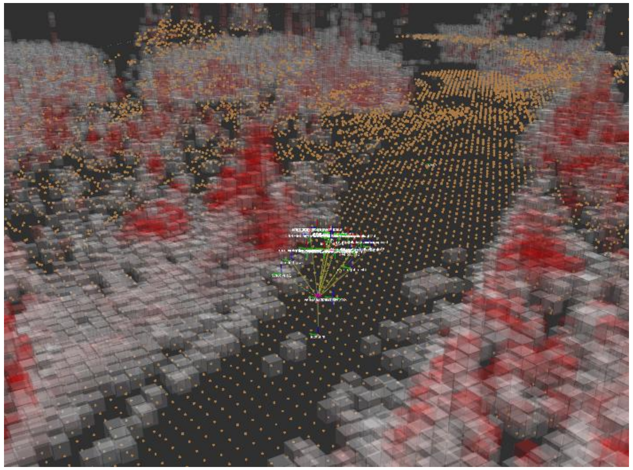
- GNSS
  - GPS
  - DRTK
  - DGPS
- Wheel Speed Encoders
- IMU
- Gyro
- RANGER
- Visual Odometry

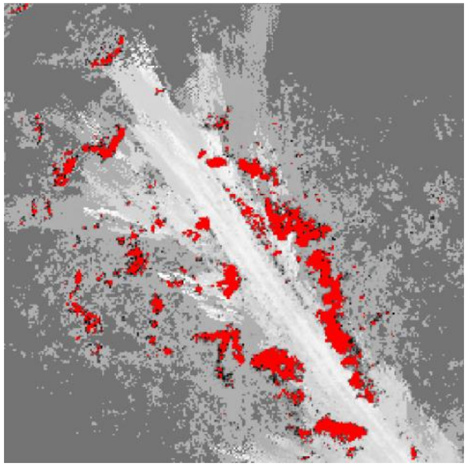
- Output:
  - far_field -> near_field -> vehicle TF tree
    - map -> odom -> base_link in standard ROS terms
  - far field and near field odometry

World Model

This subsystem is used for storing and fusing data from multiple sources. Services are provided to request data as a costmap or list of dynamic objects and zones.

- Input:
  - Plugin-based sensor fusion from Perception & Localization
  - “No go” zones
  - Known Obstacles
- Internal operations:
  - Octree-based sparse voxel map
  - Persistent Map
- Output:
  - Voxels
  - 2D Costmaps





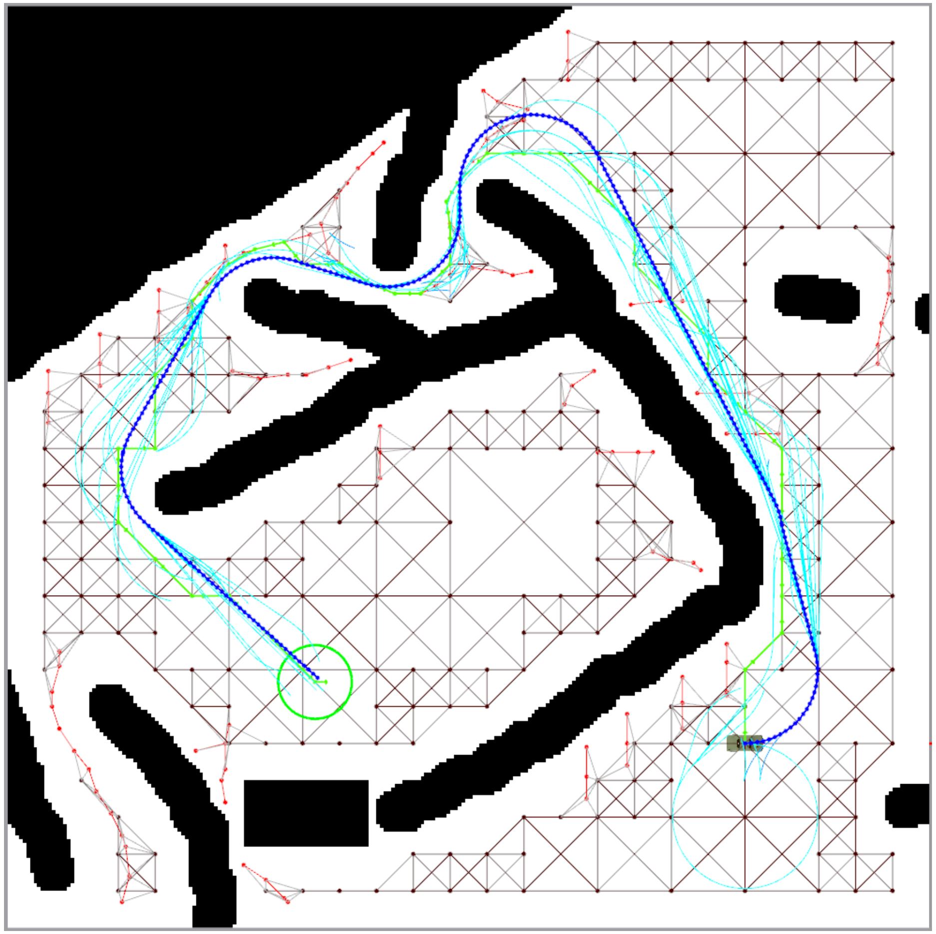
Autonomy Mode Manager

This subsystem configures and monitors behavior modules.

- Input:
  - Mode commands
- Output:
  - Path planner configuration

This subsystem generates paths and speed/steering commands to guide the vehicle to its destination.

- Input:
  - Filtered 2D Costmaps
  - Vehicle Odometry
- Internal operations:
  - Behavior switch
  - Path Planning
    - A*
    - Maverick
    - Vaquero
    - Vaquerito
- Output:
  - Speed & Curvature Setpoint



Vehicle Management System

This subsystem monitors overall health and ensures commands are safe to perform.

- Input:
  - Direct teleoperation
  - Mode commands
  - Camera control and configuration
  - Speed and steering
  - Vehicle status
- Output:
  - Mode confirmation
  - Verified speed and steering

Motion Execution

This subsystem handles primitive control and status between the autonomy kit and the drive-by-wire kit.

- Input:
  - Speed & Curvature Setpoint
  - Vehicle Odometry
- Output:
  - Drive-by-Wire Commands

Other Subsystems

- Diagnostics
  - This subsystem provides a way to monitor the health of hardware in the system.
- IOP Bridge
  - This subsystem is the interface between the autonomy kit and the operator control unit.
- CAN-A-Kit Bridge
  - This subsystem handles traffic to and from the CAN bus.
- Payload System
  - This subsystem handles control, configuration, and status of pan/tilt, camera, and remote weapon systems that can be controlled by the operator.

Vehicle Configuration

Sensors

- GNSS*
  - GPS
  - RTK
  - DGPS
- IMU*
- LIDAR*
- Wheel Speed Encoders**
- Gyro**
- Stereo Cameras
- Teleop Cameras
- Data Radios
- UWB Radios
- RADAR

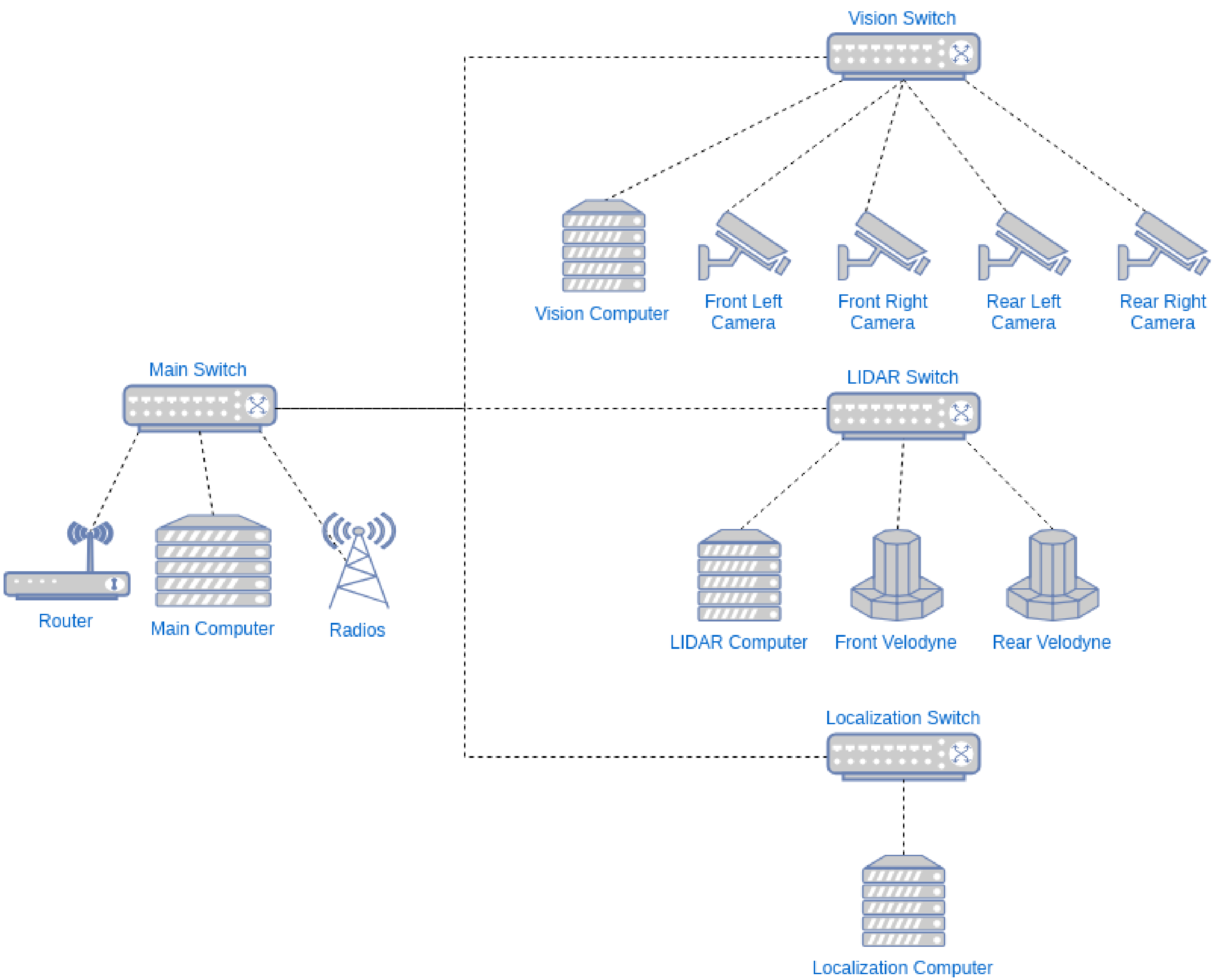
* Required

** Not required, but a really good idea

Computers

- Main
  - ROS Master
  - Navigation
  - World Model
  - Motion Execution
- Localization
  - Hardware Drivers
    - GPS
    - IMU
    - Wheel Speed
  - State Estimation
- Vision
  - Camera Drivers
  - Image Rectification
  - Disparity Segmentation
  - Material Classification
- LIDAR
  - Velodyne Drivers
  - Ground Segmentation

Networking



Vision Switch
Vision Computer
Front Left Camera
Front Right Camera
Rear Left Camera
Rear Right Camera
Main Switch
LIDAR Switch
Router
Main Computer
Radios
LIDAR Computer
Front Velodyne
Rear Velodyne
Localization Switch
Localization Computer

Development

Workflow

- Create a ROS workspace
  - Clone repositories
  - Configure the workspace
  - Install dependencies
  - Build it
- Make changes
  - Edit code
  - Deploy to a vehicle
  - Test the changes
  - Push them to a new branch
  - Create a Merge Request to request a code review

Deployment (Traditional)

- “deploy” script copies compiled binaries to /opt/rtk/indigo (or kinetic)
- Ubuntu 14.04 / ROS Indigo:
  - Upstart script in /etc/init/dsat.conf
  - sudo service dsat start/stop/restart
- Ubuntu 16.04 / ROS Kinetic:
  - Systemd unit in /etc/system/system/dsat.service
  - sudo systemctl start/stop/restart dsat

Developer Resources

- DI2E: Widely-Available Release Repository
  – RTK Core
  – WMI Core
- Dismount-Git: Primary Development Repository
  – RTK Master Branch
  – RTK Project Branches
- Developer Handbook: Environment Setup, Development Workflow, Style Guide, etc.
- RTK User Guide
  – Architecture Diagrams, Flow Charts, Use Cases
- RTK Architecture Guide
  – Low-level ROS package documentation
  – ROS node APIs

Useful Tools

Calibration

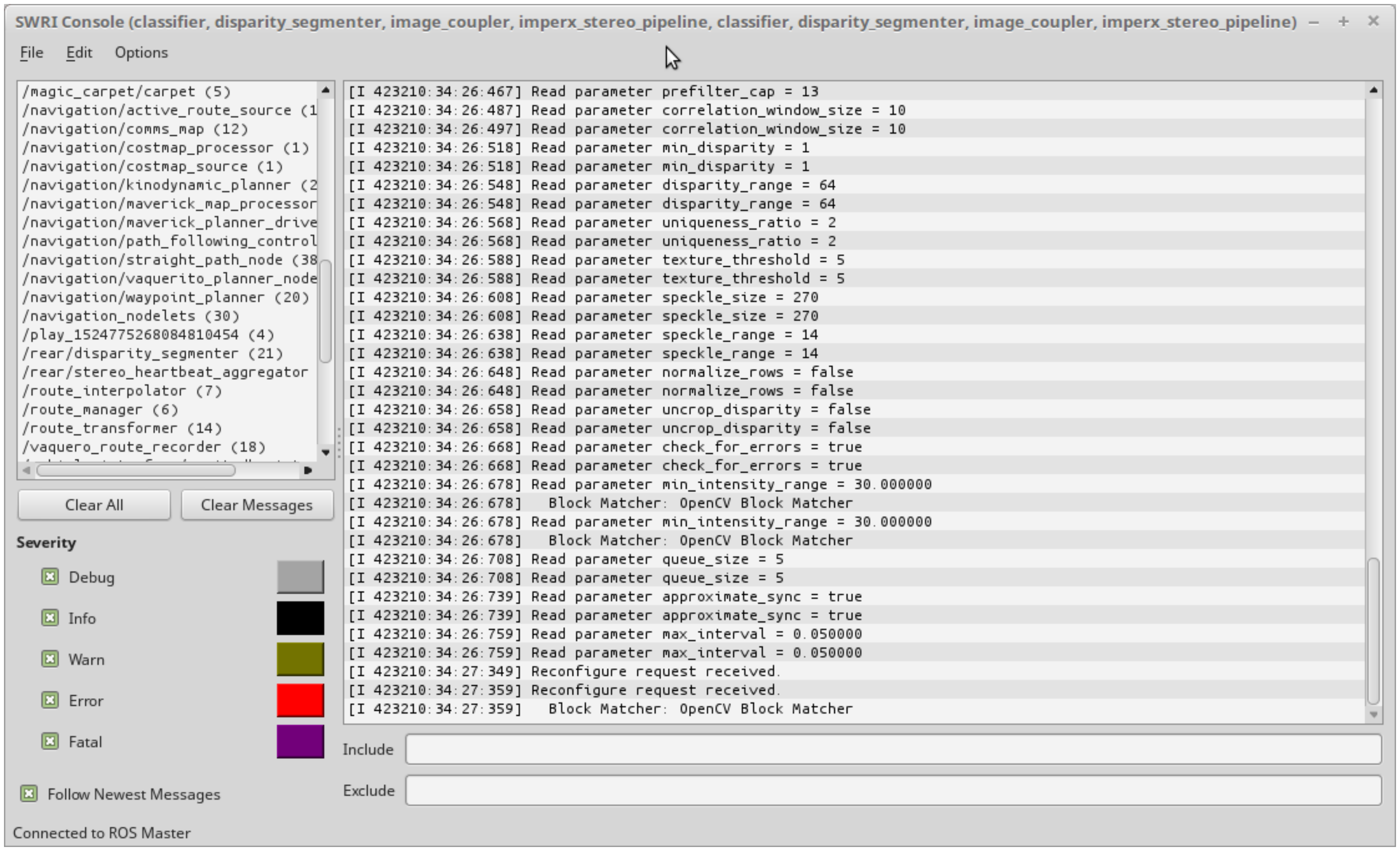
- Stereo Camera Calibration
  - Create calibration boards
  - Collect data
  - Perform calibration
  - Apply calibration files
- LIDAR Alignment
  - Necessary if using more than one LIDAR
  - Launch the calibration system
  - Run rviz to monitor progress
  - Use calibration system to manually align LIDARs
  - Save calibration values into platform launch file

Playback Mode

- `roslaunch mrzr_8803 mrzr_8803.launch playback:=true`
- Runs all nodes on the local computer
- Disables hardware drivers
- Useful for playing back bag files to debug behavior
- `rosbag play -clock -r 0.5 rtk_raw_test_track_playback*.bag \ local_xy_origin:=local_xy_old`

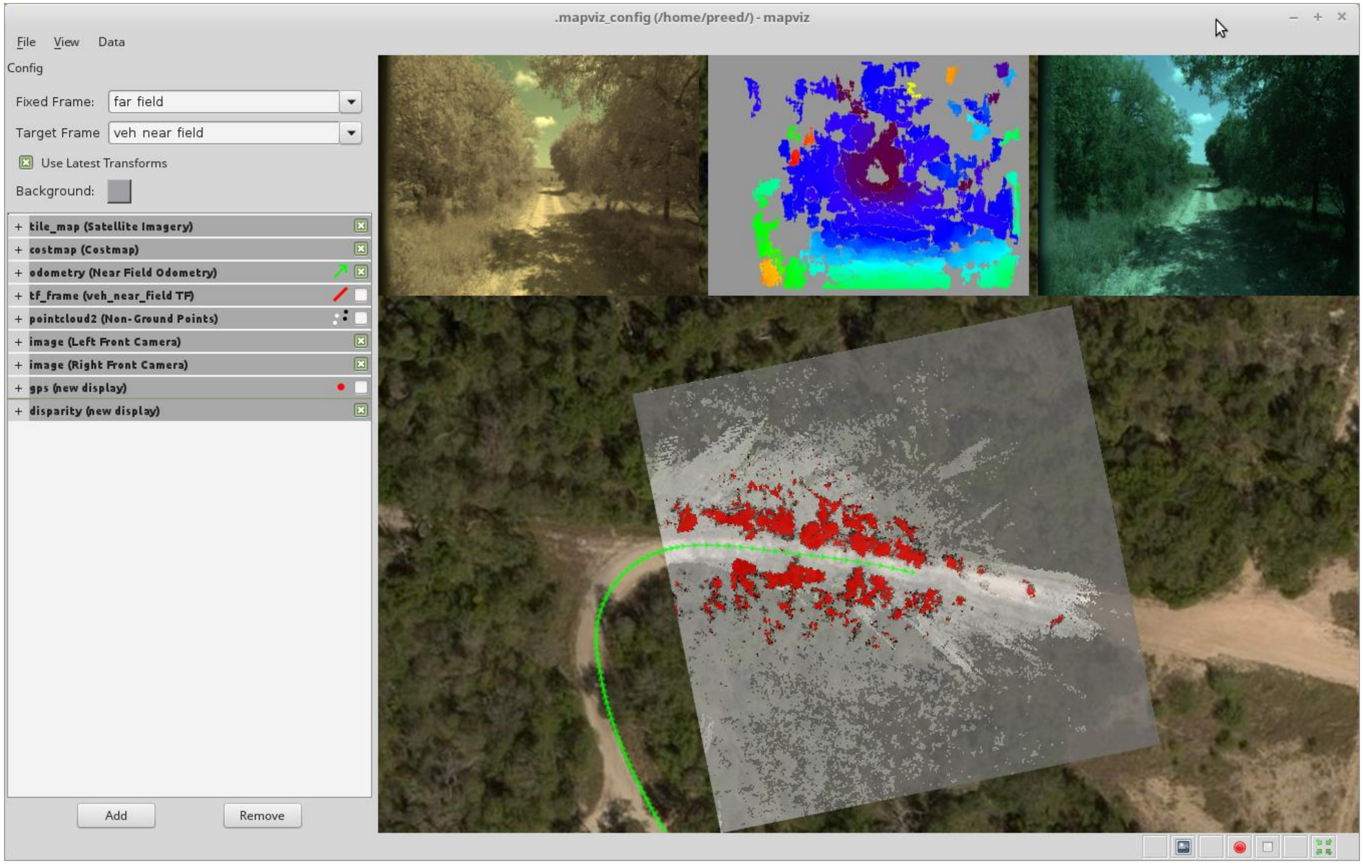
swri_console

- Like rosconsole but better



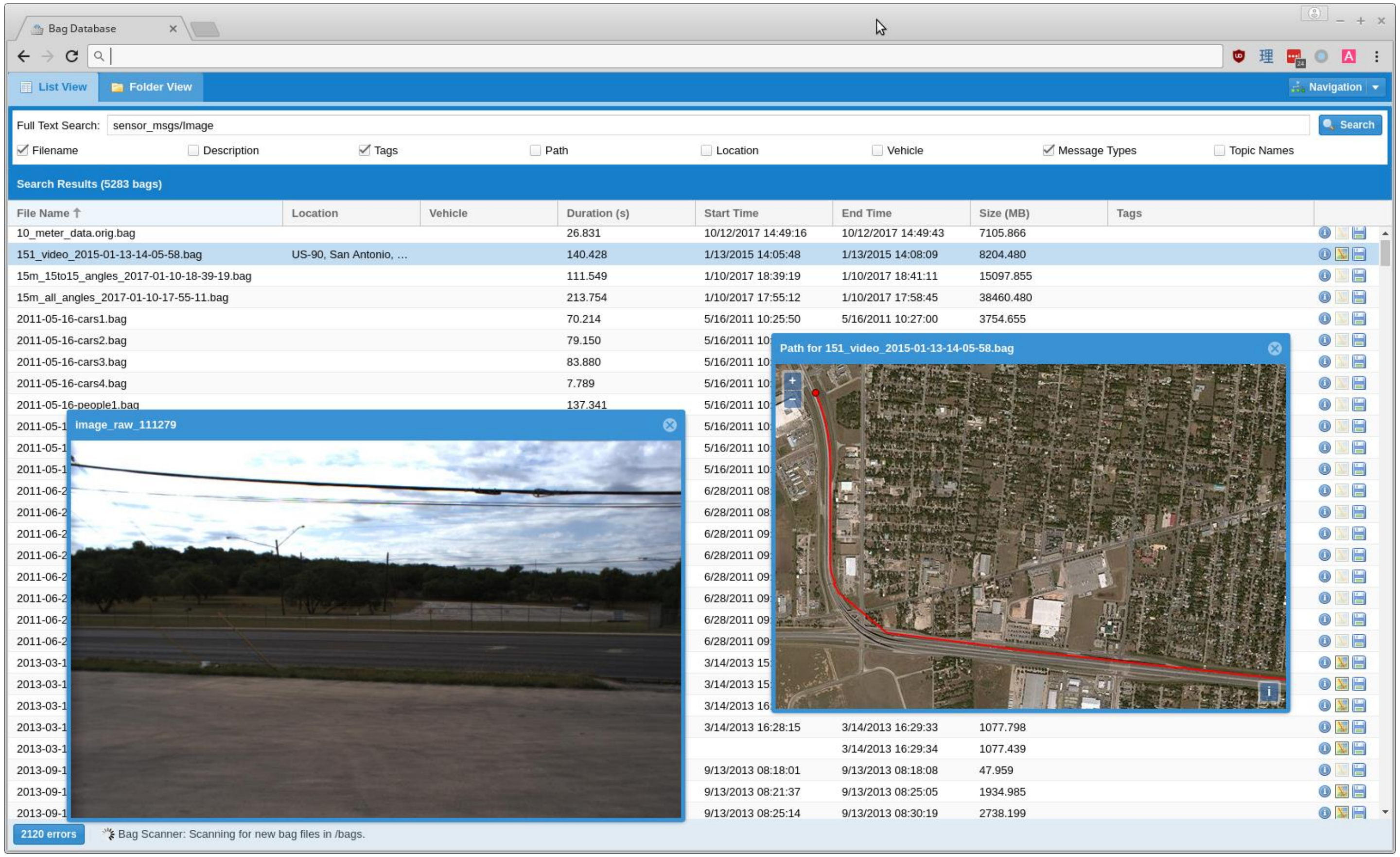
mapviz

- Top-down ROS visualization tool, similar to rviz



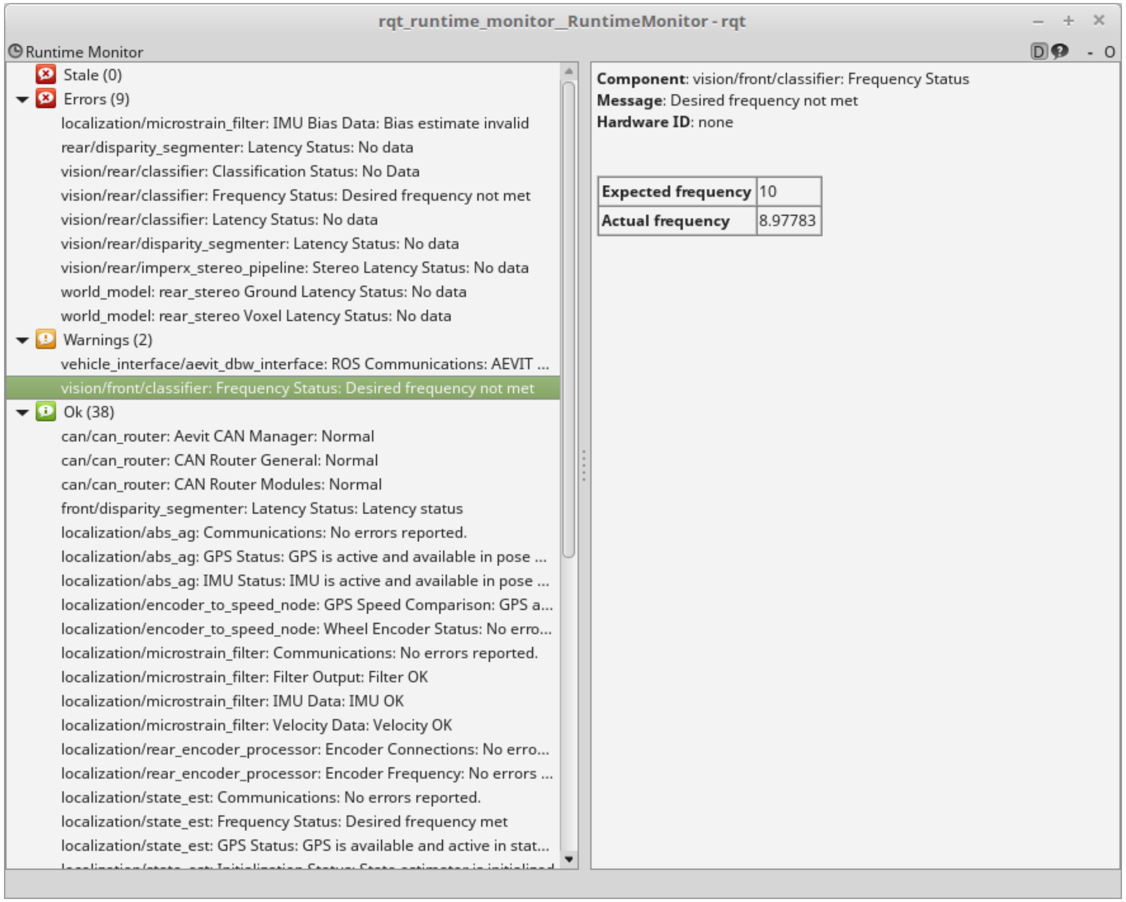
Bag Database

- Searchable, inspectable database of bag metadata



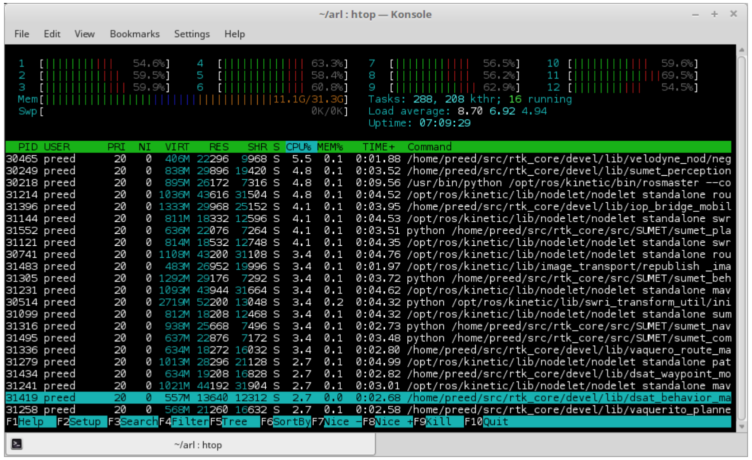
rqt_runtime_monitor

- Displays diagnostic messages
- Useful on a live vehicle to tell if all the hardware is working

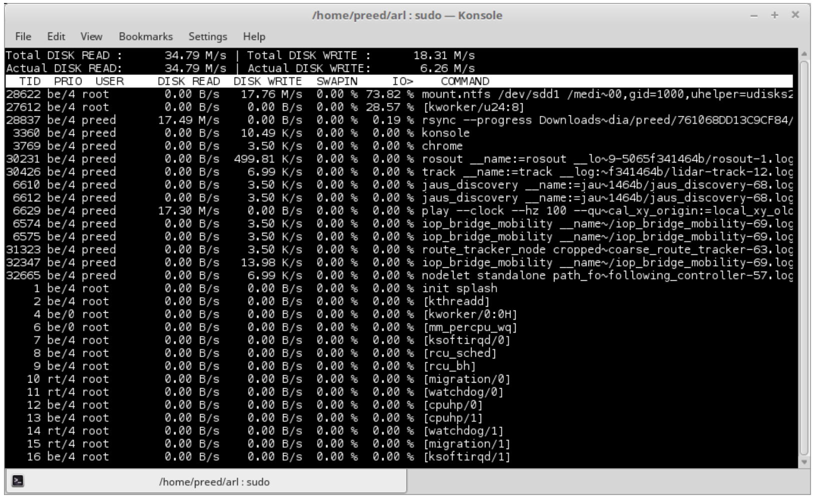


Miscellaneous Linux Utilities

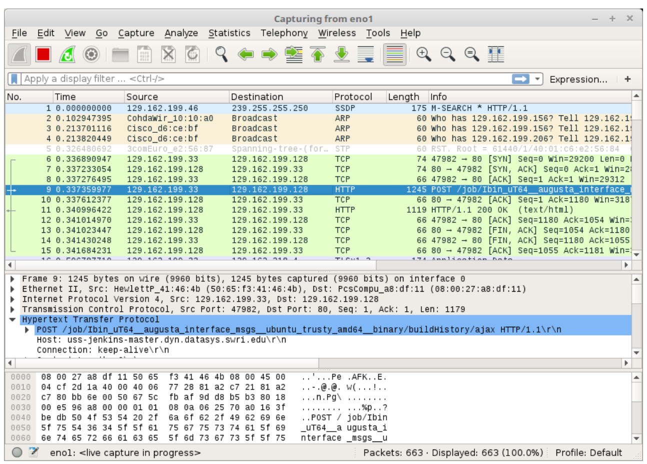
htop



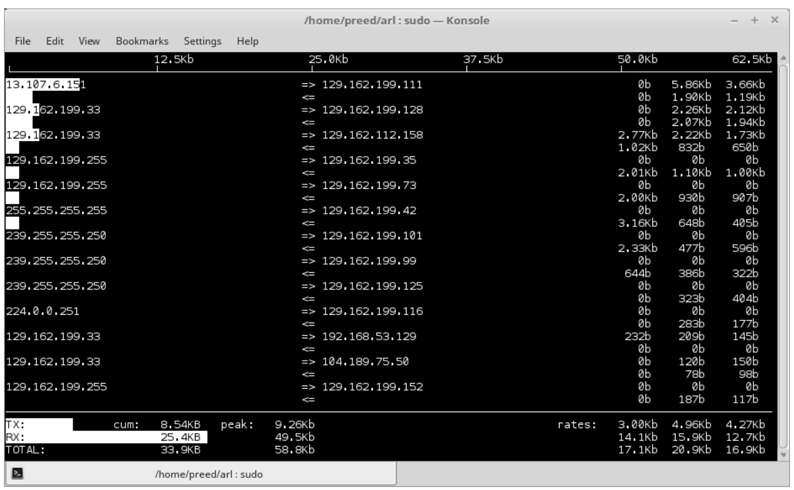
iotop



wireshark



iftop



Questions?