

ROSCon 2022

# System Modes – Model-based Run-time State Management of Large Systems

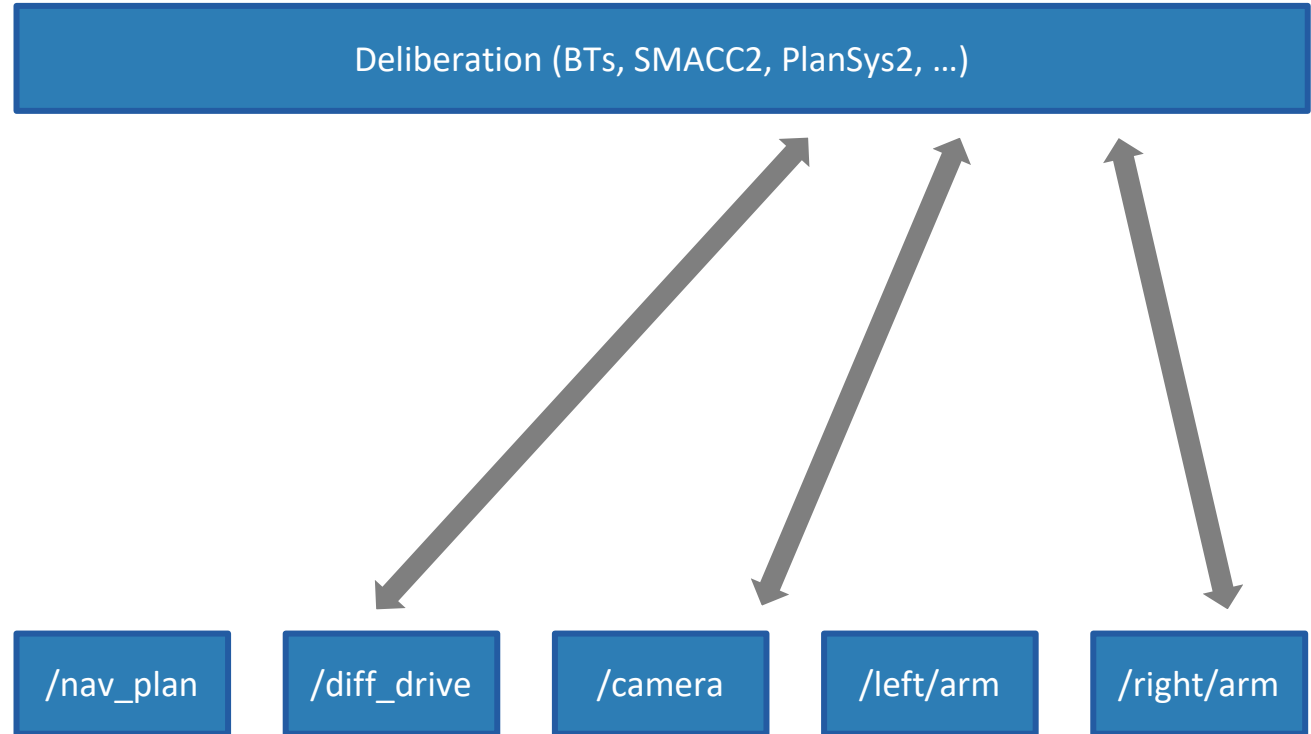
Ralph Lange, Bosch Research  
Arne Nordmann, NEURA Robotics

# System Modes

## Deliberation in robotics is complex

Three interwoven aspects:

1. Intended tasks
2. Contingencies
3. System-level errors

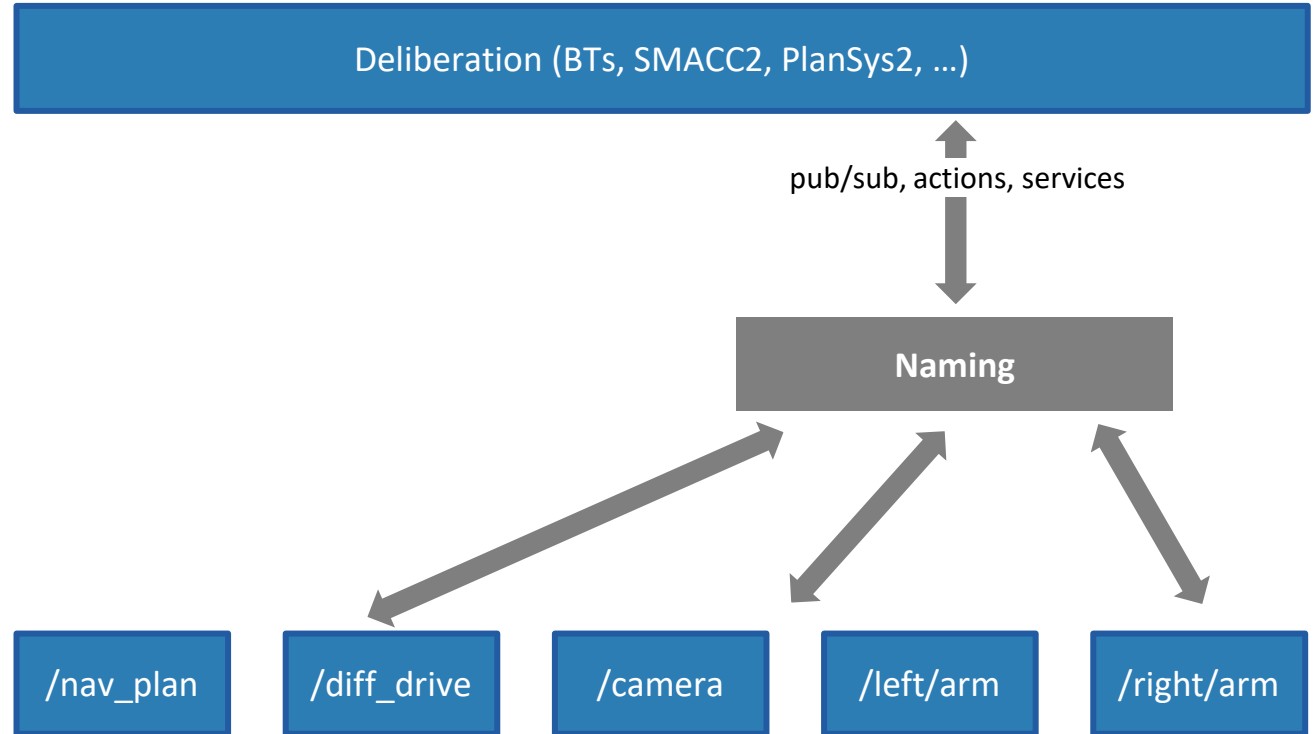


# System Modes

## Abstractions improve maintenance and extensibility

Missing abstractions for:

- ▶ States and lifecycle
- ▶ Parameters
- ▶ Diagnostics

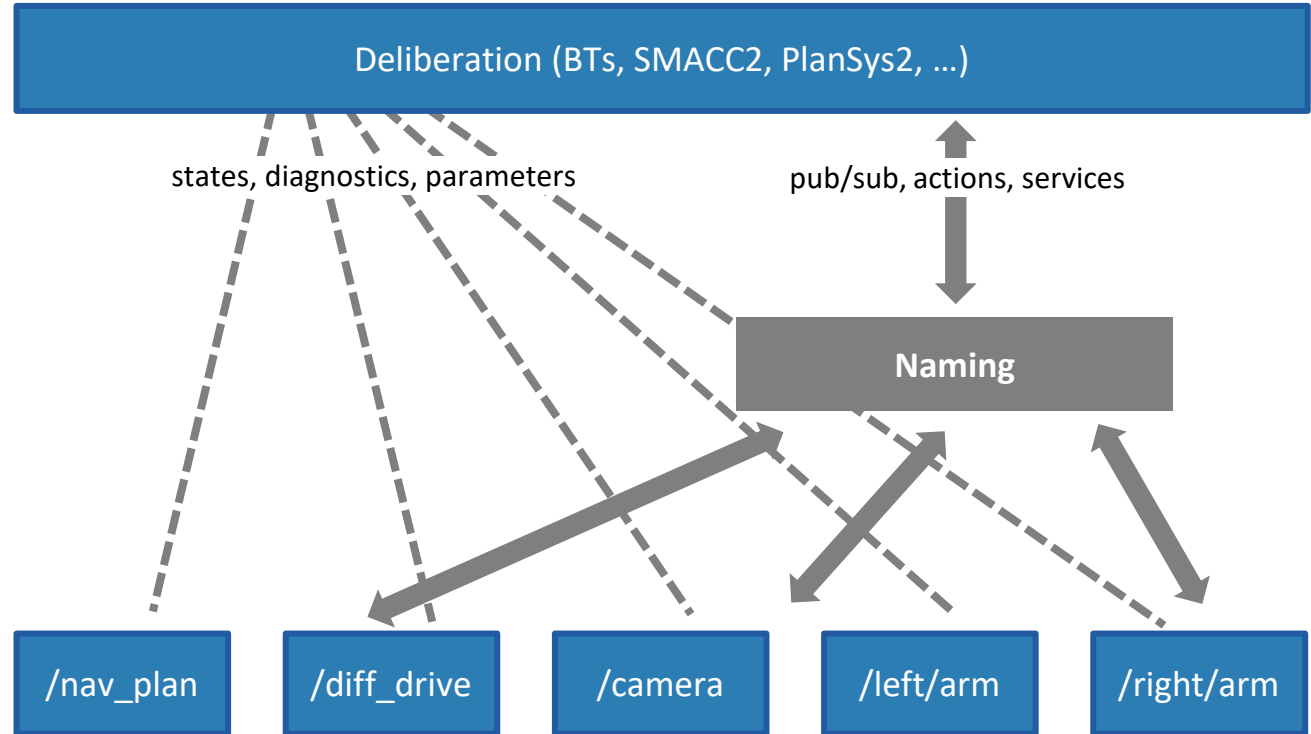


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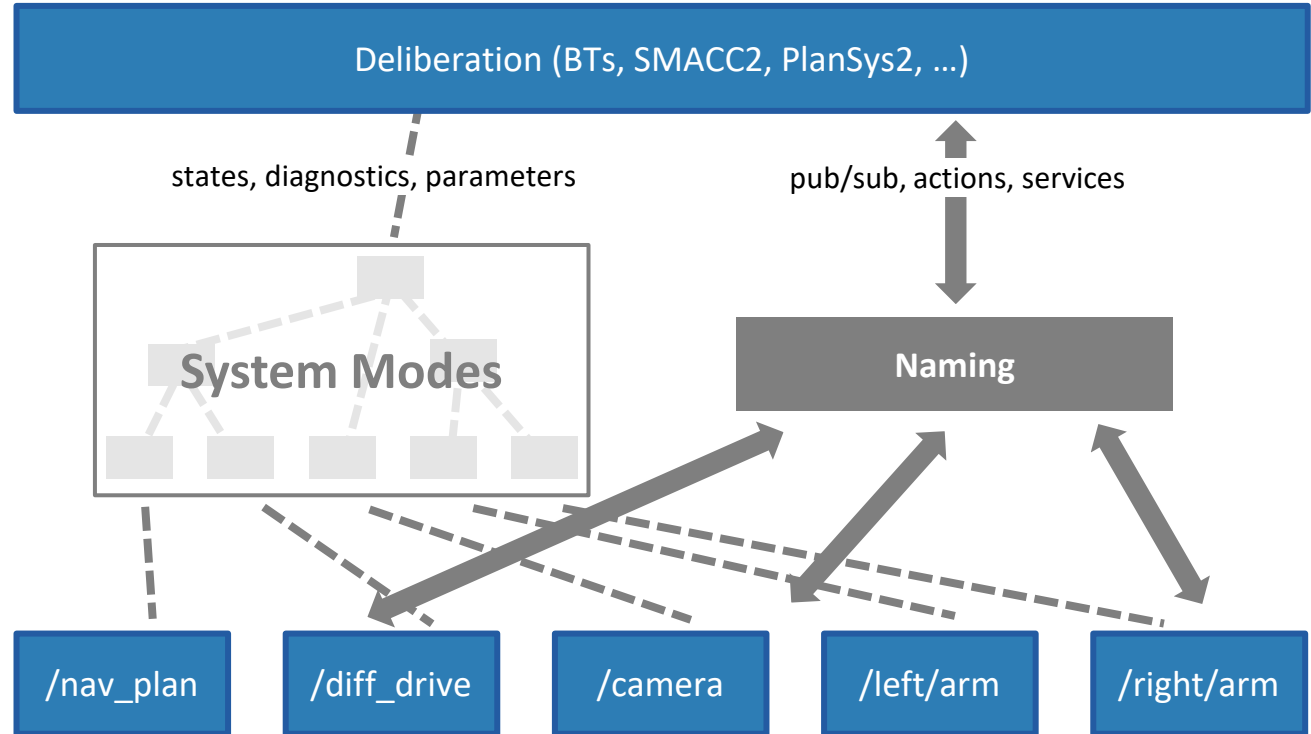


# System Modes

## Abstractions improve maintenance and extensibility

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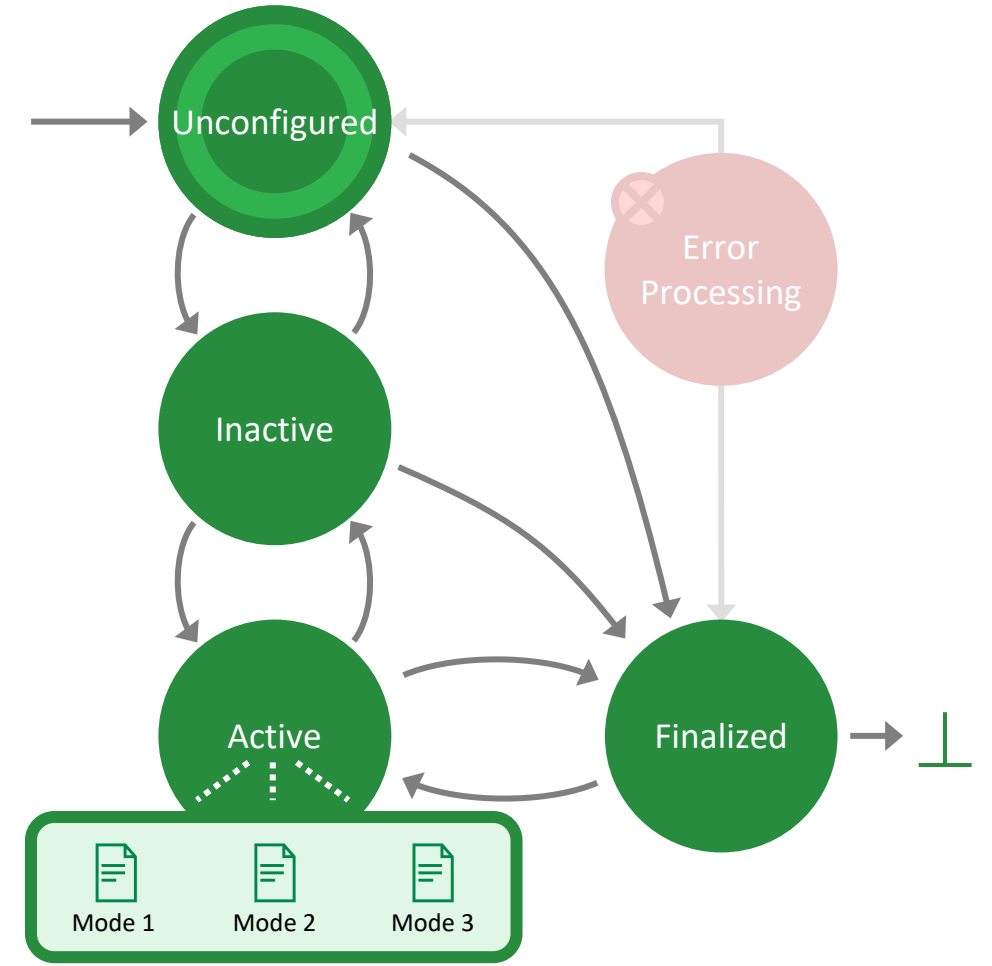
- ▶ States and lifecycle
- ▶ Parameters
- ▶ Diagnostics



# System Modes Concepts

## 1. Modes for lifecycle nodes

- ▶ Parameter value sets



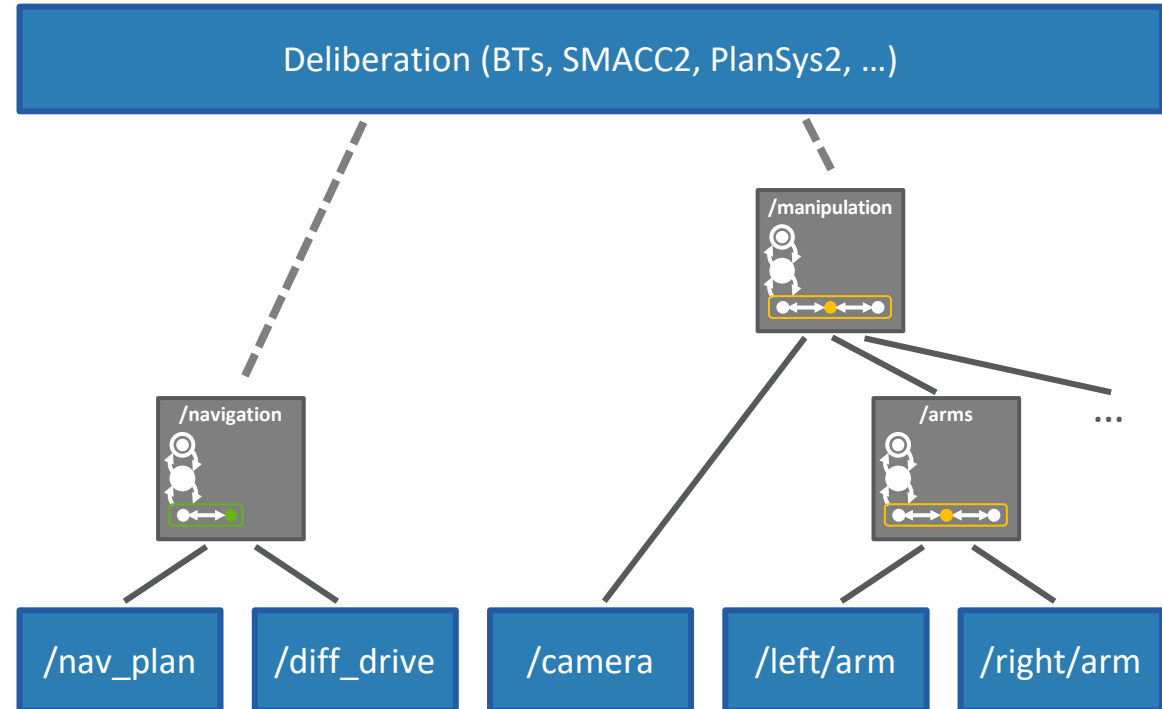
# System Modes Concepts

## 1. Modes for lifecycle nodes

- ▶ Preconfigured parameter value sets

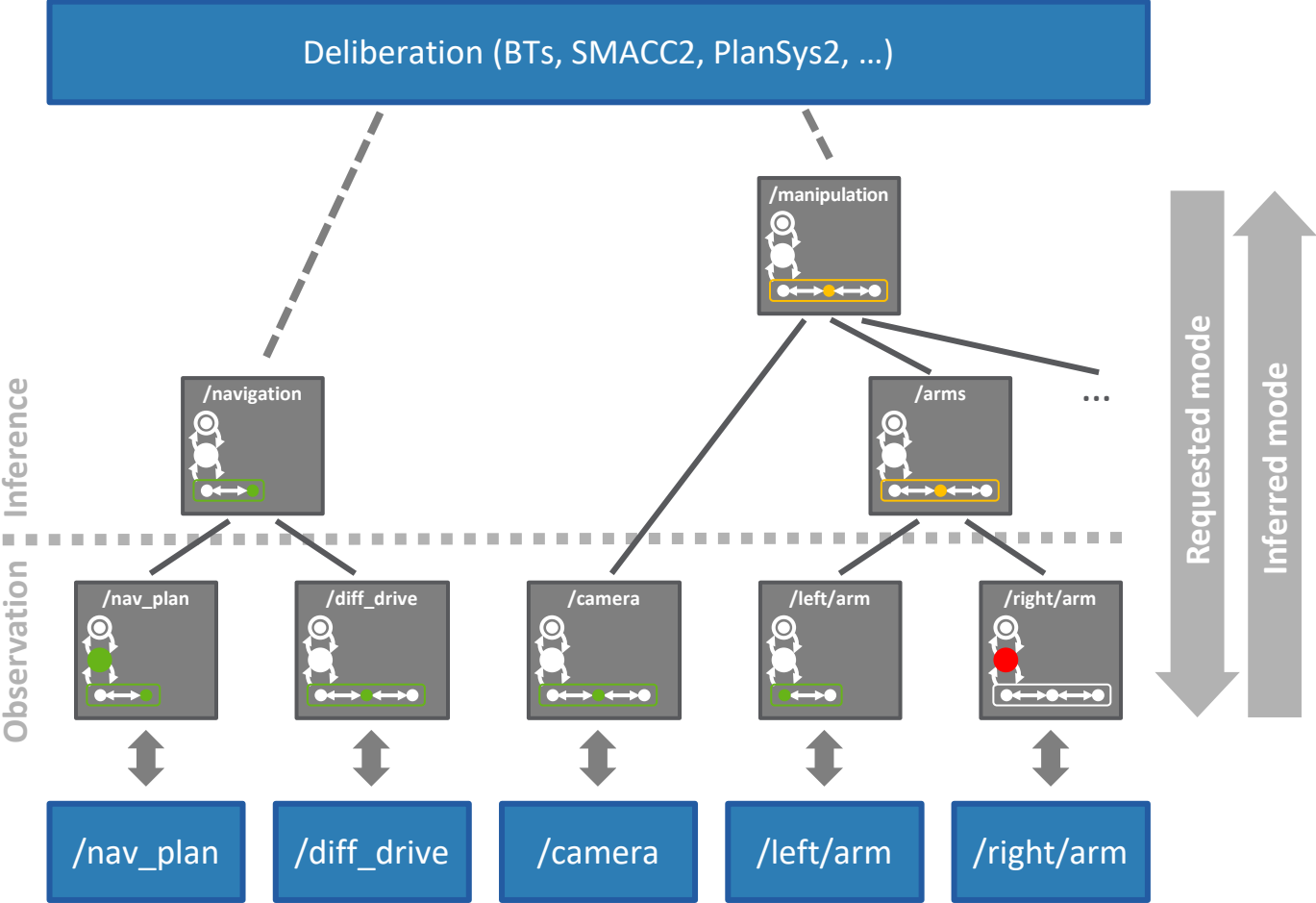
## 2. Hierarchy

- ▶ Recursive grouping of nodes into (sub-)systems
- ▶ Same lifecycle as nodes



# System Modes Concepts

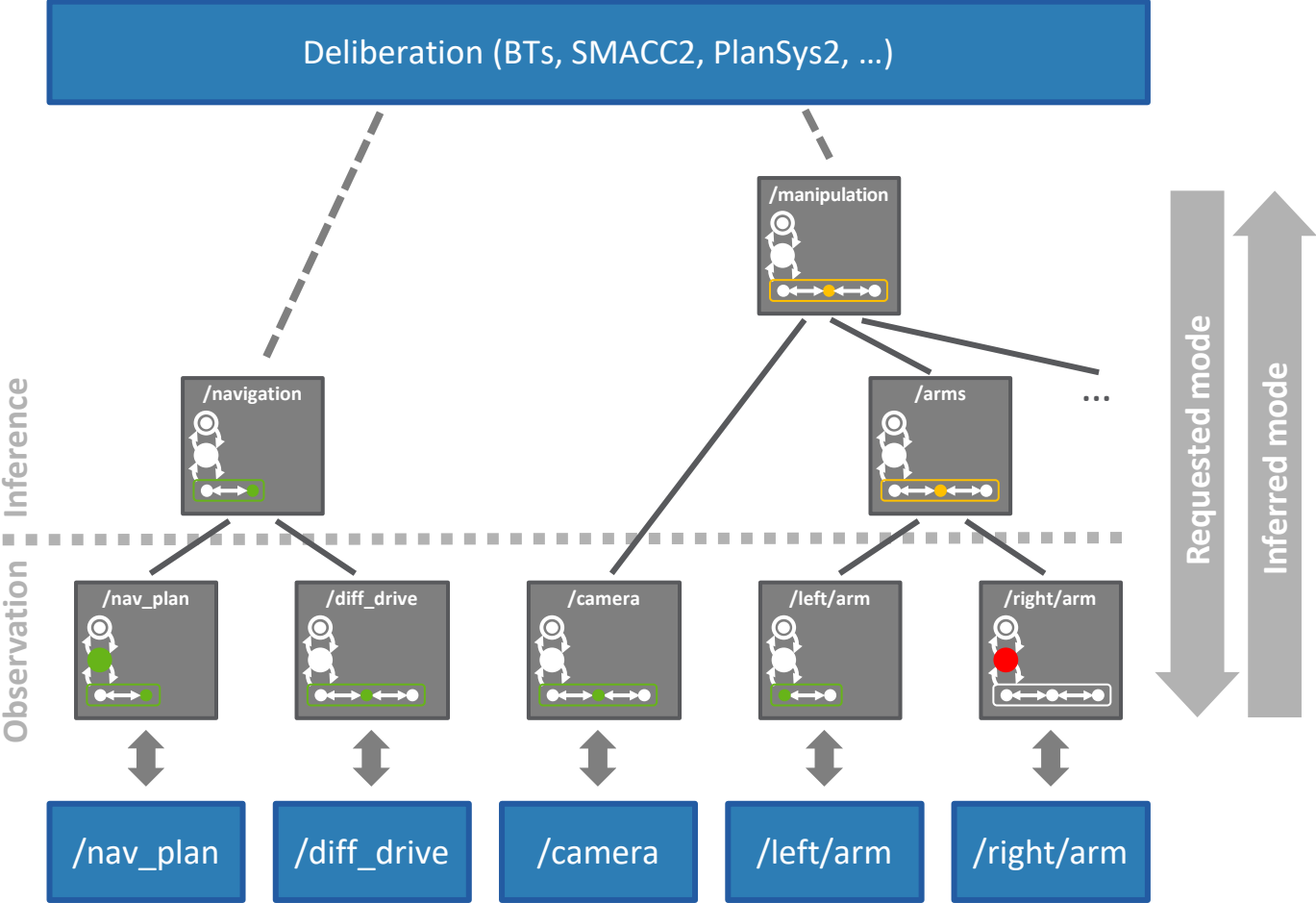
- 1. Modes for lifecycle nodes
  - ▶ Preconfigured parameter value sets
- 2. Hierarchy
  - ▶ Recursive grouping of nodes into (sub-)systems
  - ▶ Same lifecycle as nodes
- 3. Modes of (sub-)systems
  - ▶ Mapping to states + modes of their parts
  - ▶ Inference upwards along the hierarchy





# System Modes Implementation

- ▶ Virtual layer implemented by System Modes **Manager Node**
- ▶ **No changes** to lifecycle node class!
- ▶ System hierarchy, states, modes, parameter values are specified in YAML



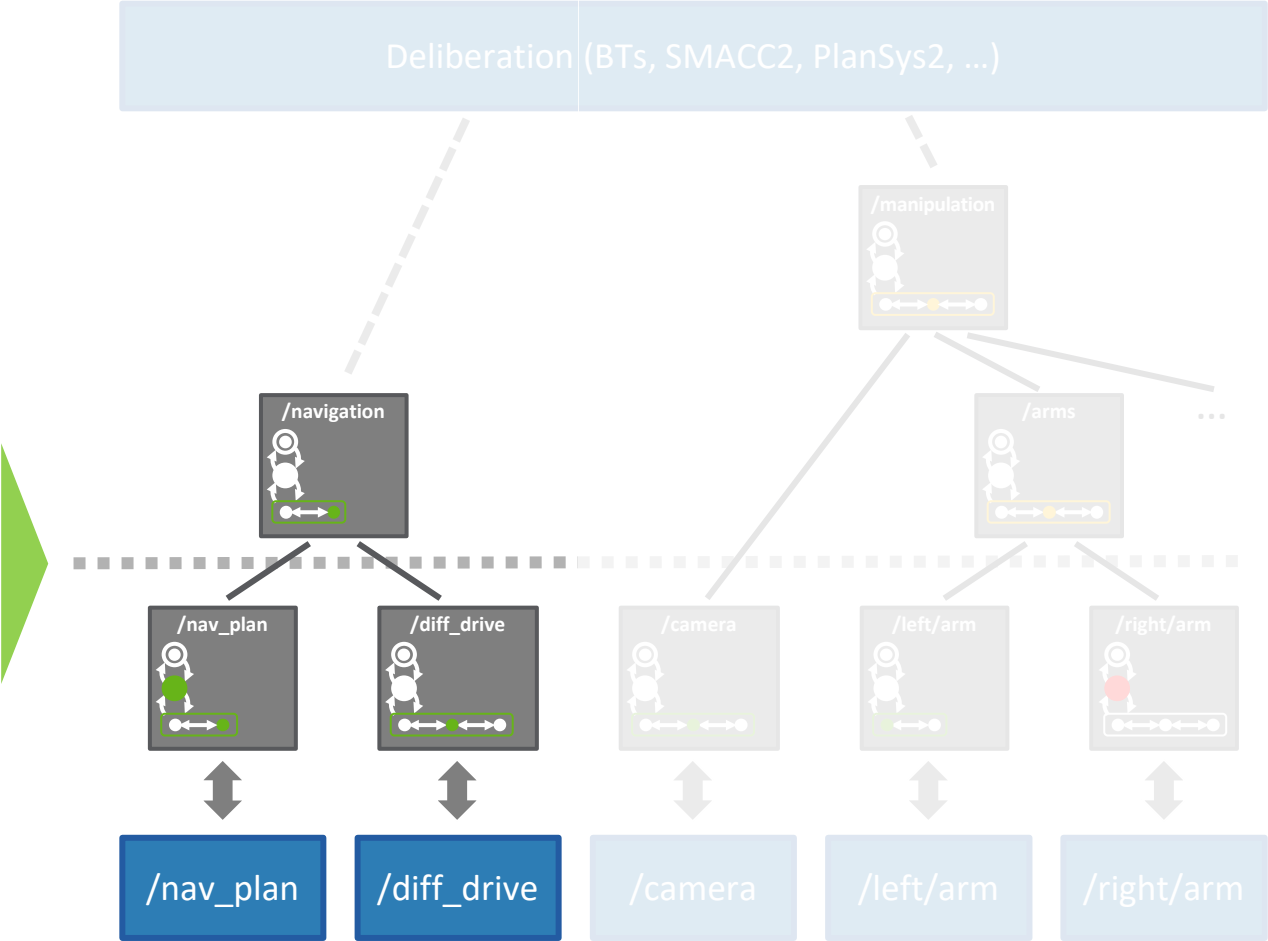
```
> ros2 launch system_modes mode_manager.launch.py modelfile:=~/my_shm.yaml
```

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```
> ros2 launch system_modes mode_monitor.launch.py modelfile:=~/my_shm.yaml
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# System Modes Example

	DEFAULT	Moderate	Performance
/nav_plan	inactive	active.Slow	active.Fast
/diff_drive	active	active.Slow	active.Fast



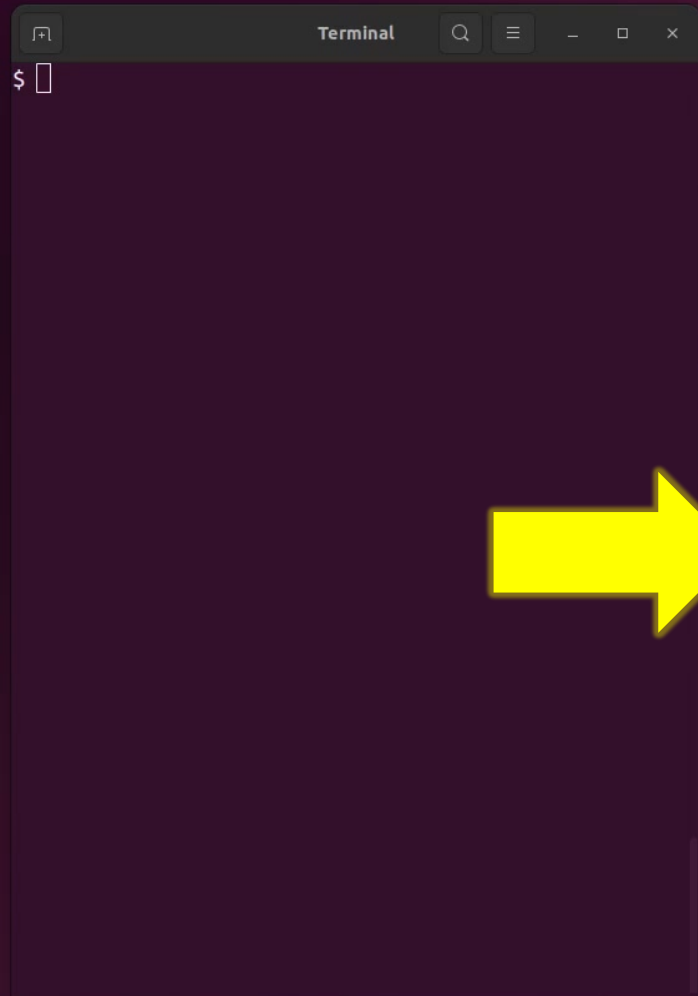
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Terminal
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Terminal
[mode_manager-1] [INFO] [1666030212.801506358] [__mode_manager]: - system 'navigation'
[mode_manager-1] [INFO] [1666030212.801633772] [__mode_manager]: - navigation/change_state
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[mode_monitor-1] Model: ./example_modes.yaml
[mode_monitor-1]
[mode_monitor-1]
[mode_monitor-1]      part | state | mode |
[mode_monitor-1] -----|-----|-----|
[mode_monitor-1] - systems -----|-----|-----|
[mode_monitor-1]      navigation |      |      |
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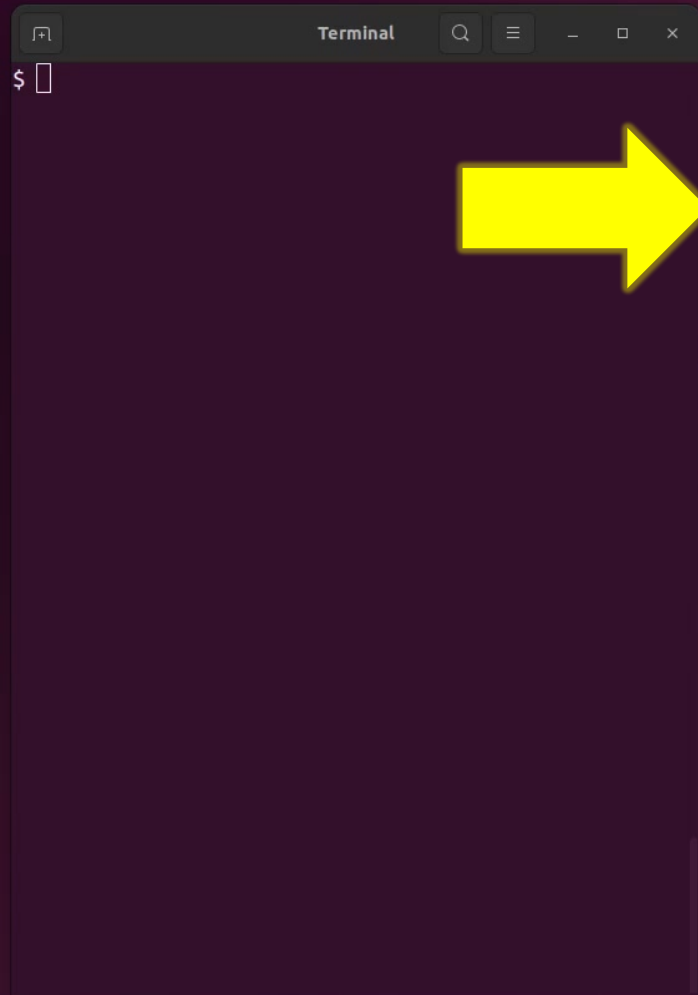


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|                            | part       | target | state  | target | mode   |
|----------------------------|------------|--------|--------|--------|--------|
|                            |            |        | actual |        | actual |
| [mode_monitor-1] - systems | navigation |        |        |        |        |
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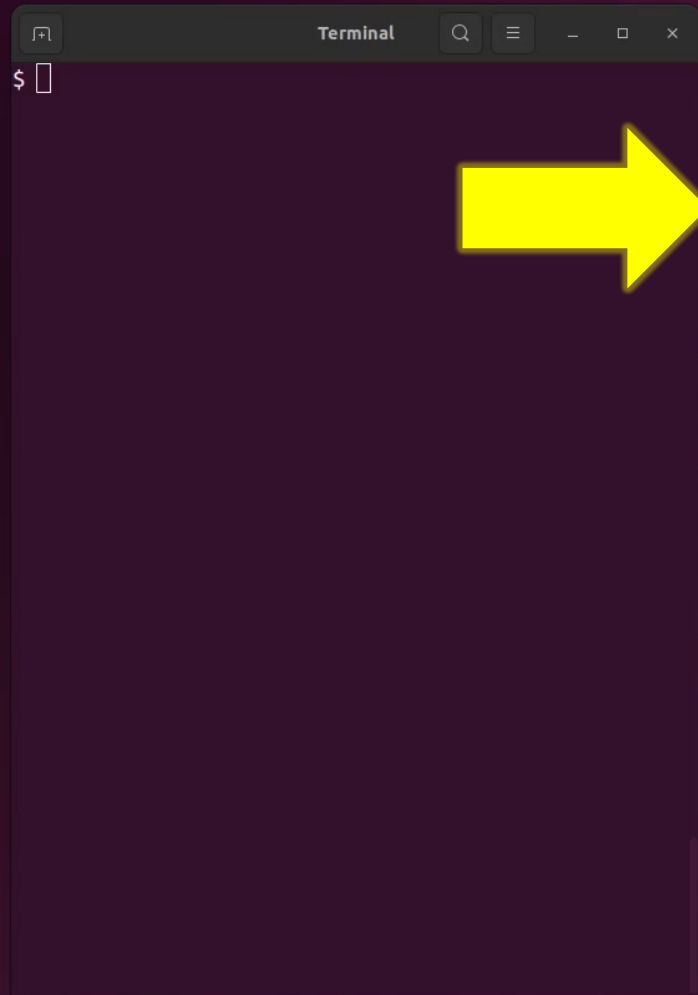
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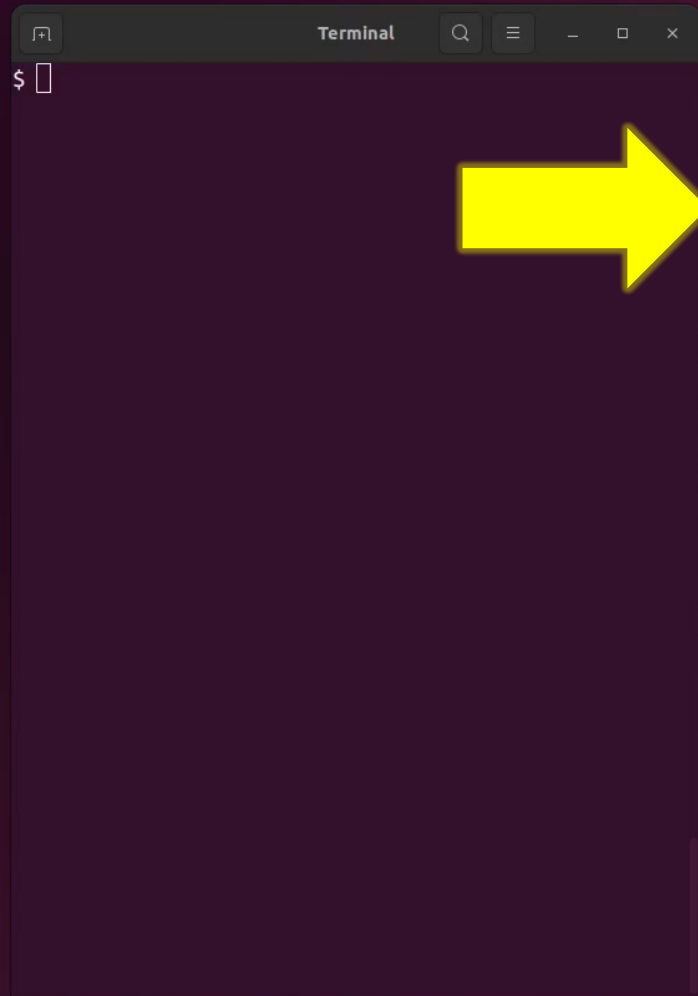


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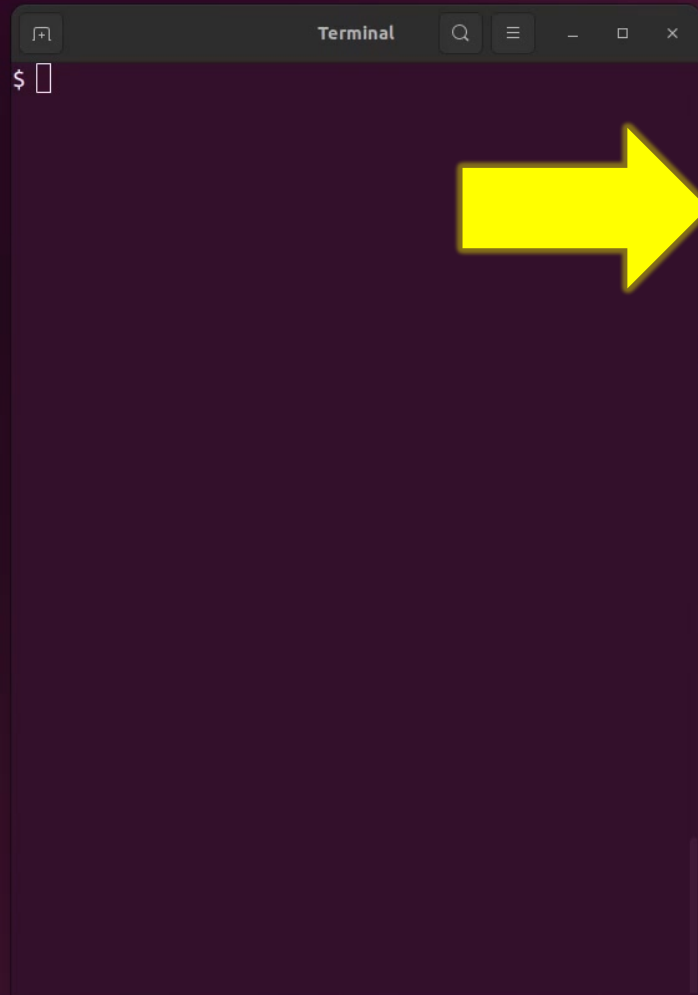


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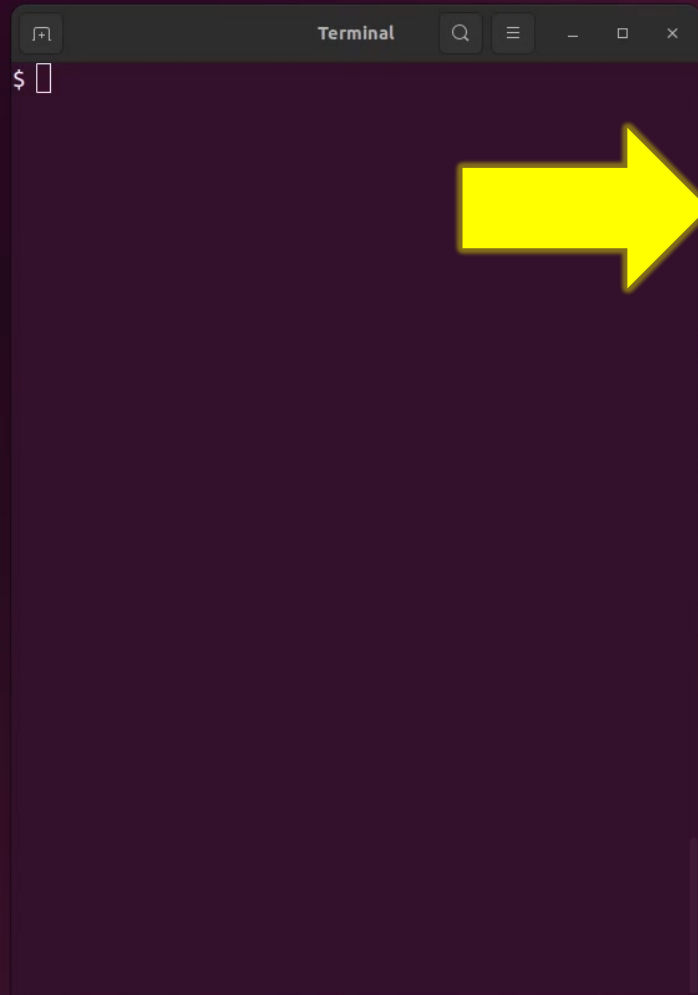


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[mode_manager-1] [INFO] [1666030212.801737360] [__mode_manager]: - navigation/get_available_modes
[mode_manager-1] [INFO] [1666030212.810673260] [__mode_manager]: - node 'diff_drive'
[mode_manager-1] [INFO] [1666030212.810712885] [__mode_manager]: - diff_drive/change_mode
[mode_manager-1] [INFO] [1666030212.810730201] [__mode_manager]: - diff_drive/get_mode
[mode_manager-1] [INFO] [1666030212.810744559] [__mode_manager]: - diff_drive/get_available_modes
[mode_manager-1] [INFO] [1666030212.818652826] [__mode_manager]: - node 'nav_plan'
[mode_manager-1] [INFO] [1666030212.818710124] [__mode_manager]: - nav_plan/change_mode
[mode_manager-1] [INFO] [1666030212.818730275] [__mode_manager]: - nav_plan/get_mode
[mode_manager-1] [INFO] [1666030212.818744871] [__mode_manager]: - nav_plan/get_available_modes
```

```
Terminal
[nav_plan-1] [INFO] [1666030222.775283138] [nav_plan]: Constructed lifecycle node 'nav_plan'
```

```
[diff_drive-1] [INFO] [1666030218.323982983] [diff_drive]: Constructed lifecycle node 'diff_drive'
```

```
Terminal
System Modes Monitor - Mon Oct 17 20:14:40 2022
[mode_monitor-1] Model: ./example_modes.yaml
[mode_monitor-1]
[mode_monitor-1]
[mode_monitor-1]      part | state | mode |
[mode_monitor-1]      -----|-----|-----|
[mode_monitor-1] - systems -----|-----|-----|
[mode_monitor-1]      navigation |      |      |
[mode_monitor-1] - nodes -----|-----|-----|
[mode_monitor-1]      diff_drive |      |      |
[mode_monitor-1]      nav_plan   |      |      |
[mode_monitor-1]
[mode_monitor-1] -----|-----|-----|
```

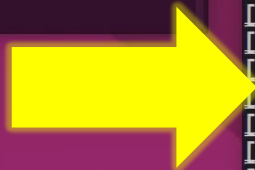
```
Terminal
$
```

```
Terminal
[mode_manager-1] [INFO] [1666030212.801506358] [__mode_manager]: - system 'navigation'
[mode_manager-1] [INFO] [1666030212.801633772] [__mode_manager]: - navigation/change_state
[mode_manager-1] [INFO] [1666030212.801659487] [__mode_manager]: - navigation/get_state
[mode_manager-1] [INFO] [1666030212.801679736] [__mode_manager]: - navigation/get_available_states
[mode_manager-1] [INFO] [1666030212.801699291] [__mode_manager]: - navigation/change_mode
[mode_manager-1] [INFO] [1666030212.801718353] [__mode_manager]: - navigation/get_mode
[mode_manager-1] [INFO] [1666030212.801737360] [__mode_manager]: - navigation/get_available_modes
[mode_manager-1] [INFO] [1666030212.810673260] [__mode_manager]: - node 'diff_drive'
[mode_manager-1] [INFO] [1666030212.810712885] [__mode_manager]: - diff_drive/change_mode
[mode_manager-1] [INFO] [1666030212.810730201] [__mode_manager]: - diff_drive/get_mode
[mode_manager-1] [INFO] [1666030212.810744559] [__mode_manager]: - diff_drive/get_available_modes
[mode_manager-1] [INFO] [1666030212.818652826] [__mode_manager]: - node 'nav_plan'
[mode_manager-1] [INFO] [1666030212.818710124] [__mode_manager]: - nav_plan/change_mode
[mode_manager-1] [INFO] [1666030212.818730275] [__mode_manager]: - nav_plan/get_mode
[mode_manager-1] [INFO] [1666030212.818744871] [__mode_manager]: - nav_plan/get_available_modes
```

```
Terminal
[nav_plan-1] [INFO] [1666030222.775283138] [nav_plan]: Constructed lifecycle node 'nav_plan'
```

```
[diff_drive-1] [INFO] [1666030218.323982983] [diff_drive]: Constructed lifecycle node 'diff_drive'
```

```
Terminal
System Modes Monitor - Mon Oct 17 20:14:40 2022
[mode_monitor-1] Model: ./example_modes.yaml
[mode_monitor-1]
[mode_monitor-1]
[mode_monitor-1]      part | state | mode |
[mode_monitor-1]      -----|-----|-----|
[mode_monitor-1] - systems -----|-----|-----|
[mode_monitor-1]      navigation |      |      |
[mode_monitor-1] - nodes -----|-----|-----|
[mode_monitor-1]      diff_drive |      |      |
[mode_monitor-1]      nav_plan  |      |      |
[mode_monitor-1]
[mode_monitor-1]
[mode_monitor-1]
[mode_monitor-1]
```



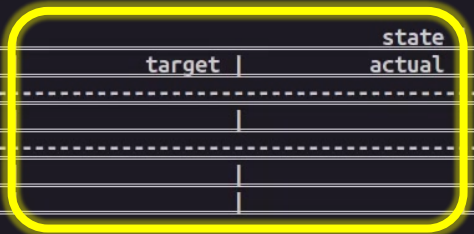
```
Terminal
$
```

```
Terminal
[mode_manager-1] [INFO] [1666030212.801506358] [__mode_manager]: - system 'navigation'
[mode_manager-1] [INFO] [1666030212.801633772] [__mode_manager]: - navigation/change_state
[mode_manager-1] [INFO] [1666030212.801659487] [__mode_manager]: - navigation/get_state
[mode_manager-1] [INFO] [1666030212.801679736] [__mode_manager]: - navigation/get_available_states
[mode_manager-1] [INFO] [1666030212.801699291] [__mode_manager]: - navigation/change_mode
[mode_manager-1] [INFO] [1666030212.801718353] [__mode_manager]: - navigation/get_mode
[mode_manager-1] [INFO] [1666030212.801737360] [__mode_manager]: - navigation/get_available_modes
[mode_manager-1] [INFO] [1666030212.810673260] [__mode_manager]: - node 'diff_drive'
[mode_manager-1] [INFO] [1666030212.810712885] [__mode_manager]: - diff_drive/change_mode
[mode_manager-1] [INFO] [1666030212.810730201] [__mode_manager]: - diff_drive/get_mode
[mode_manager-1] [INFO] [1666030212.810744559] [__mode_manager]: - diff_drive/get_available_modes
[mode_manager-1] [INFO] [1666030212.818652826] [__mode_manager]: - node 'nav_plan'
[mode_manager-1] [INFO] [1666030212.818710124] [__mode_manager]: - nav_plan/change_mode
[mode_manager-1] [INFO] [1666030212.818730275] [__mode_manager]: - nav_plan/get_mode
[mode_manager-1] [INFO] [1666030212.818744871] [__mode_manager]: - nav_plan/get_available_modes
```

```
Terminal
[nav_plan-1] [INFO] [1666030222.775283138] [nav_plan]: Constructed lifecycle node 'nav_plan'
```

```
[diff_drive-1] [INFO] [1666030218.323982983] [diff_drive]: Constructed lifecycle node 'diff_drive'
```

```
Terminal
System Modes Monitor - Mon Oct 17 20:14:40 2022
[mode_monitor-1] Model: ./example_modes.yaml
[mode_monitor-1]
[mode_monitor-1]
[mode_monitor-1]      part      target | state | target | mode |
[mode_monitor-1]      -----|-----|-----|-----|
[mode_monitor-1] - systems -----|-----|-----|-----|
[mode_monitor-1]      navigation |      |      |      |
[mode_monitor-1] - nodes -----|-----|-----|-----|
[mode_monitor-1]      diff_drive |      |      |      |
[mode_monitor-1]      nav_plan  |      |      |      |
[mode_monitor-1]
[mode_monitor-1] -----|-----|-----|-----|
```



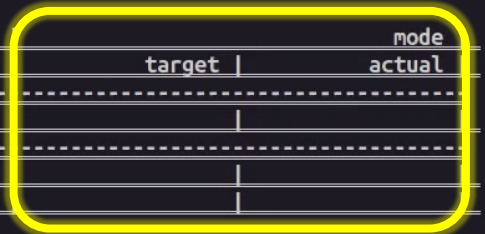
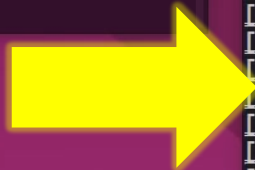
```
Terminal
$
```

```
Terminal
[mode_manager-1] [INFO] [1666030212.801506358] [__mode_manager]: - system 'navigation'
[mode_manager-1] [INFO] [1666030212.801633772] [__mode_manager]: - navigation/change_state
[mode_manager-1] [INFO] [1666030212.801659487] [__mode_manager]: - navigation/get_state
[mode_manager-1] [INFO] [1666030212.801679736] [__mode_manager]: - navigation/get_available_states
[mode_manager-1] [INFO] [1666030212.801699291] [__mode_manager]: - navigation/change_mode
[mode_manager-1] [INFO] [1666030212.801718353] [__mode_manager]: - navigation/get_mode
[mode_manager-1] [INFO] [1666030212.801737360] [__mode_manager]: - navigation/get_available_modes
[mode_manager-1] [INFO] [1666030212.810673260] [__mode_manager]: - node 'diff_drive'
[mode_manager-1] [INFO] [1666030212.810712885] [__mode_manager]: - diff_drive/change_mode
[mode_manager-1] [INFO] [1666030212.810730201] [__mode_manager]: - diff_drive/get_mode
[mode_manager-1] [INFO] [1666030212.810744559] [__mode_manager]: - diff_drive/get_available_modes
[mode_manager-1] [INFO] [1666030212.818652826] [__mode_manager]: - node 'nav_plan'
[mode_manager-1] [INFO] [1666030212.818710124] [__mode_manager]: - nav_plan/change_mode
[mode_manager-1] [INFO] [1666030212.818730275] [__mode_manager]: - nav_plan/get_mode
[mode_manager-1] [INFO] [1666030212.818744871] [__mode_manager]: - nav_plan/get_available_modes
```

```
Terminal
[nav_plan-1] [INFO] [1666030222.775283138] [nav_plan]: Constructed lifecycle node 'nav_plan'
```

```
[diff_drive-1] [INFO] [1666030218.323982983] [diff_drive]: Constructed lifecycle node 'diff_drive'
```

```
Terminal
System Modes Monitor - Mon Oct 17 20:14:40 2022
[mode_monitor-1] Model: ./example_modes.yaml
[mode_monitor-1]
[mode_monitor-1]
[mode_monitor-1]      part | state |
[mode_monitor-1]      part | target | actual |
[mode_monitor-1] - systems -----
[mode_monitor-1]      navigation |      |
[mode_monitor-1] - nodes -----
[mode_monitor-1]      diff_drive |      |
[mode_monitor-1]      nav_plan |      |
[mode_monitor-1]
[mode_monitor-1] -----
```





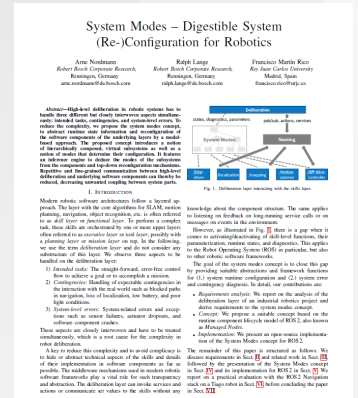


# System Modes

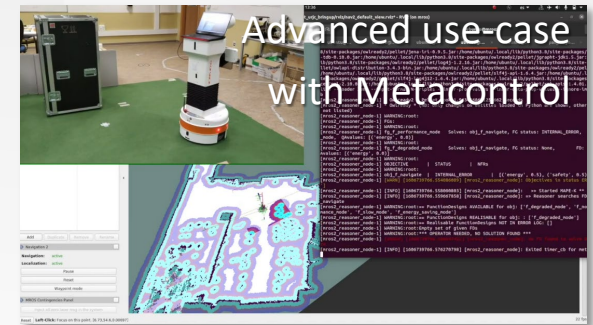
- ▶ [github.com/micro-ROS/system\\_modes](https://github.com/micro-ROS/system_modes)
- ▶ Releases: Foxy, Galactic, Humble
- ▶ Work-in-progress – Feedback welcome!

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[github.com/ralph-lange](https://github.com/ralph-lange)  
[github.com/norro](https://github.com/norro)



A. Nordmann, R. Lange, and F. M. Rico:  
System Modes – Digestible System  
(Re-)Configuration for Robotics.  
*Proc. of 3rd Int'l Workshop on RoSE. 2021.*



<https://youtu.be/j67xXNldRkQ>