

# Software requirements

- Python package manager **uv**
  - <https://docs.astral.sh/uv/getting-started/installation/>
  - You can pre-cache Python 3.10 and any more modern ones
  - You can pre-cache Python packages:
    - *jupyterlab, trame, trame-vuetify, vtk, trame-vtk, trame-vtklocal*
- ParaView 5.13.3
  - <https://www.paraview.org/download/>
- Browser (Chrome, Firefox or from system)
  - <https://www.google.com/chrome/>
  - <https://www.mozilla.org/en-US/firefox/>
- Text / Code editor (anything you want or VSCode)
  - <https://code.visualstudio.com/>

# Hands-On Creation of Bespoke Scientific Visualization Applications with Trame

HPC-Enabled Web, Jupyter, and Desktop  
Apps for Simulation, Experiment, and AI Data

Sebastien Jourdain (Kitware), Logan Harbour (INL), Axel Huebl (LBNL),  
Brian DeVincentis (M-Star), David Rogers (LANL), Victor Mateevitsi (ANL)



# Morning

- Trame fundamentals
    - State and events
  - Dynamic web interface
    - Vue.js templating
  - Vuetify for beautiful user interface
    - Designing a beautiful UI
- 
- 3D Visualization
    - Using VTK and ParaView
  - 2D Charts
    - Matplotlib, plotly, altair
  - Interactive data processing
    - Connecting chart selection with 3D visualization

# Afternoon

- Evolving Peacock into a more robust interface for MOOSE modeling and simulation (INL)
  - Building Interactive Dashboards for the Beam, Plasma & Accelerator Simulation Toolkit (BLAST) with trame (LBNL)
  - Skip the process bloat and run your CFD anywhere with M-Star & trame (M-Star)
- 
- Genomic visualization at scale with ParaView and trame (LANL)
  - Real-Time Simulation Control and Visualization through trame (ANL)
  - Natural Robustness Testing and Model Explainability for AI Test and Evaluation (Kitware)

# Trame fundamentals

State, Events, Widgets, UI

# What is trame?

- **Simple**

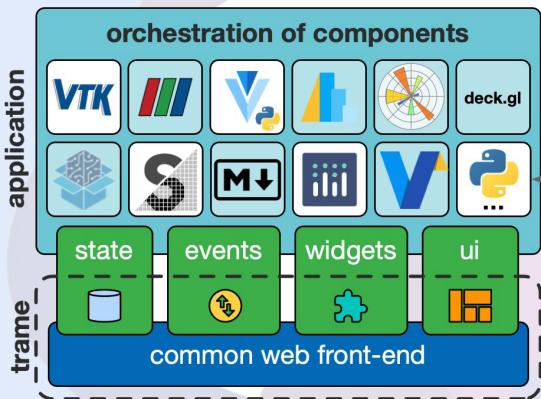
All the logic and UI definition can be done in plain Python

- **Powerful**

Python offer scientific and information data visualization with capable data processing (numpy, Plotly, Matplotlib, VTK, ParaView...)

- **Ubiquitous**

Runs on laptops, desktops, clusters, and the cloud while displaying everywhere (phone, tablet, laptop, workstation)



# What it is not?

- **Another stateless backend framework**

Take ideas from Dash and Streamlit but go beyond by enabling infinite possibilities while reducing integration/maintenance cost.

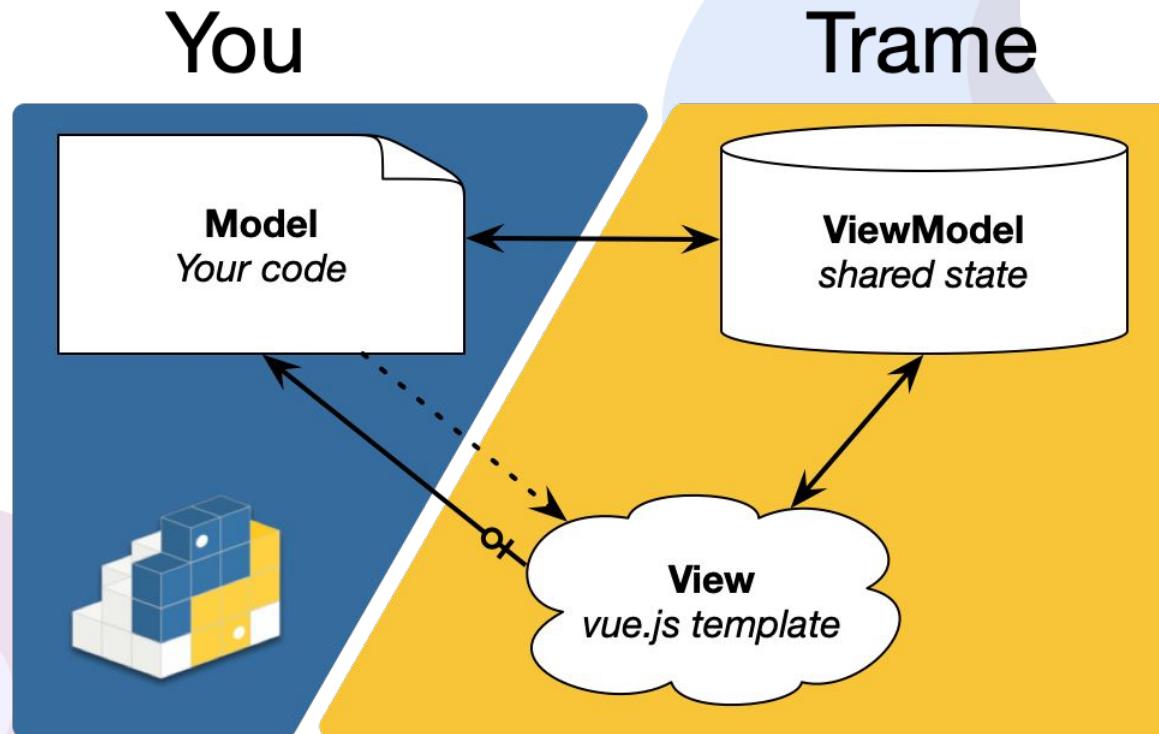
- **Another visualization/data analytic library**

It does not create something new, but enable interactive interaction with existing libraries like VTK, Plotly, matplotlib and more.

- **Another JavaScript frontend framework**

Only expect Vue.js components/plugins without any API constraint or frame specificity.

# MVVM Pattern: Model - View - ViewModel



Python

# The split

- **Model**

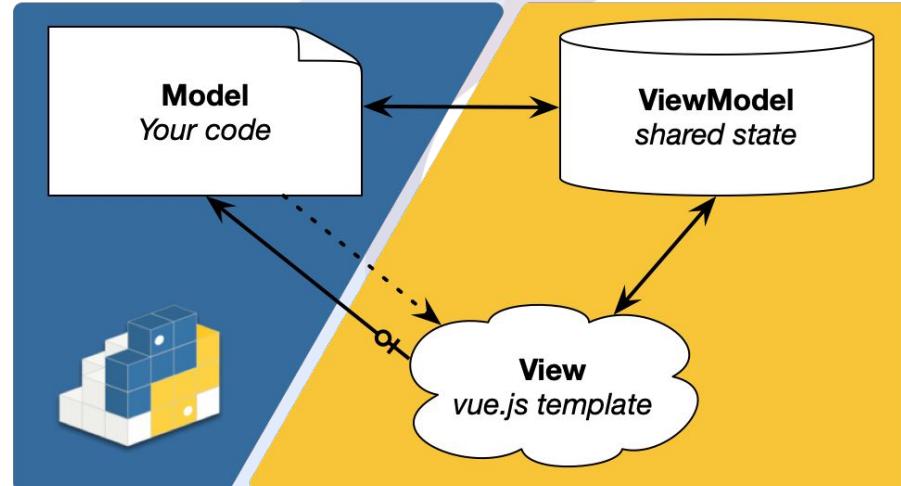
- Your business (frame does not care)

- **ViewModel**

- Reactive data model that drives the presentation layer
- The **Model** can react to changes and modify it
- The **View** reflect its state and can modify it

- **View**

- Present the **ViewModel** into a graphical form
- The **Model** can connect actions to events (click, mouse)

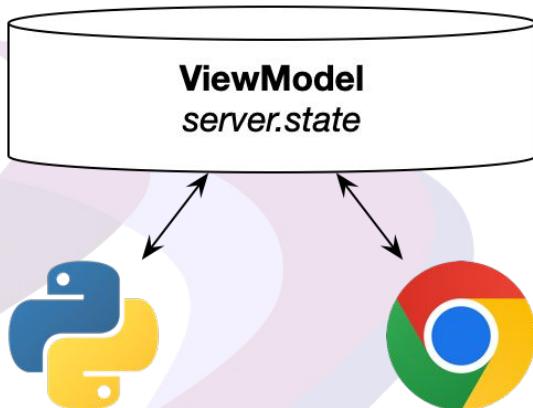


# ViewModel

Dictionary like structure to store data to present in the view. The data needs to be serializable.

## Read/Write

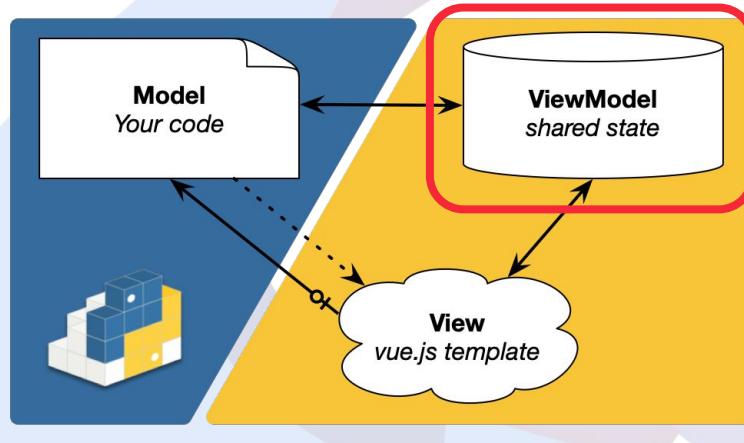
```
state.a = 1  
state["b"] = state.a * 2  
assert state.b == state["b"]
```



## Reactivity

```
@state.change("a")  
def update_b(a, **_):  
    state.b = int(a) * 2
```

```
@state.change("a", "b")  
def update_log(**_):  
    msg = ["\nChanges to"]  
    for var_name in state.modified_keys & {"a", "b"}:  
        msg.append(f"{var_name}={state[var_name]}\")  
  
    state.log += " ".join(msg)
```



# View

Template language (html/vue) in Python to ease data and event binding.



## Events and State

a=10 and b=20

### Events

Reset a Reset a & b Reset log

### States

Changes to b=2 a=1  
Changes to a=10  
Changes to b=20

```
def reset_a():
    state.a = 10

with DivLayout(server):
    html.H1("Events and State")

    html.Div("a={{ a }} and b={{ b }}")

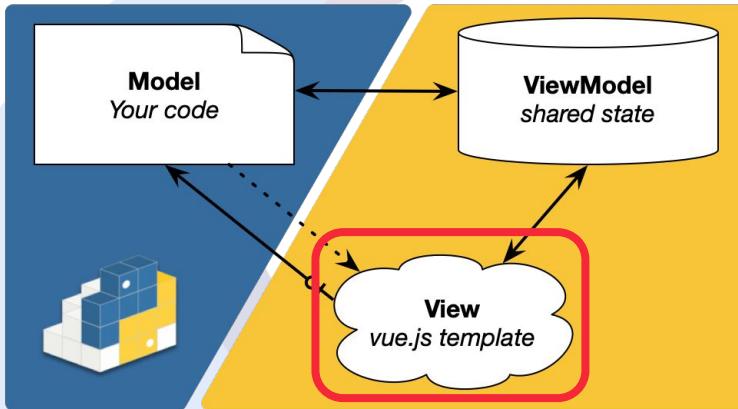
    html.H2("Events")

    html.Button("Reset a", click=reset_a)
    html.Button("Reset a & b", click="setAll({ b:2, a:1 })")
    html.Button("Reset log", click="log = ''")

    html.H2("States")

    html.Input(type="range", min=0, max=10, v_model="a")
    html.Input(type="range", min=0, max=30, v_model="b")
```

HTML



```
<div>
  <h1>
    Events and State
  </h1>
  <div>
    a={{ a }} and b={{ b }}
  </div>
  <h2>
    Events
  </h2>
  <button @click="trigger('trigger__1')">
    Reset a
  </button>
  <button @click="setAll({ b:2, a:1 })">
    Reset a & b
  </button>
  <button @click="log = ''">
    Reset log
  </button>
  <h2>
    States
  </h2>
  <input v-model="a" max="10" min="0" type="range" />
  <input v-model="b" max="30" min="0" type="range" />
  <br />
  <textarea style="width: 15rem;" v-model="log" disabled rows="12" />
</div>
```

# Full application

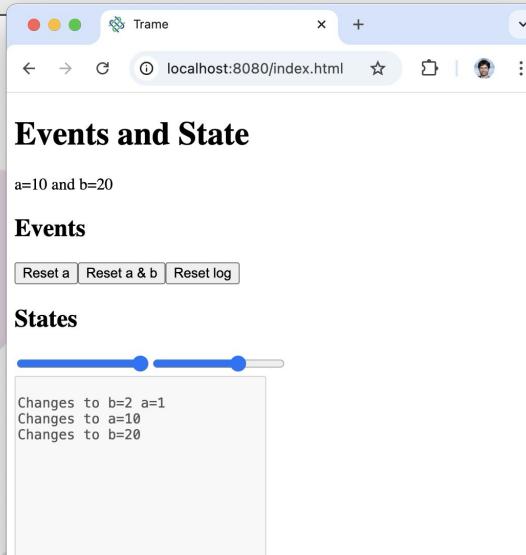
```
1  from trame.app import get_server
2  from trame.widgets import html
3  from trame.ui.html import DivLayout
4
5  # Trame setup -----
6  server = get_server()
7
8  # ViewModel -----
9  state = server.state
10
11 # Read/Write
12 state.a = 1
13 state["b"] = state.a * 2
14 assert state.b == state["b"]
15
16
17 # Reactivity
18 @state.change("a")
19 def update_b(a, **_):
20     state.b = int(a) * 2
21
22
23 @state.change("a", "b")
24 def update_log(**_):
25     msg = ["\nChanges to"]
26     for var_name in state.modified_keys & {"a", "b"}:
27         msg.append(f"{var_name}={state[var_name]}")
28
29     state.log += " ".join(msg)
30
31
32 @state.change("log")
33 def trim_log(log, **_):
34     lines = log.split("\n")
35     if len(lines) > 10:
36         state.log = "\n".join(lines[-10:])
37
38
39 # Model -----
40 def reset_a():
41     state.a = 10
42
43
44 # View -----
45 with DivLayout(server):
46     html.H1("Events and State")
47
48     html.Div("a={{ a }} and b={{ b }}")
49
50     html.H2("Events")
51
52     html.Button("Reset a", click=reset_a)
53     html.Button("Reset a & b", click="setAll({ b:2, a:1 })")
54     html.Button("Reset log", click="log = ''")
55
56     html.H2("States")
57
58     html.Input(type="range", min=0, max=10, v_model="a")
59     html.Input(type="range", min=0, max=30, v_model="b")
60
61     html.Br()
62
63     html.Textarea(
64         v_model=("log", ""),
65         disabled=True,
66         rows=12,
67         style="width: 15rem;",
68     )
69
70 # Start Server -----
71 server.start()
```

The screenshot shows a browser window for the Trame application at `localhost:8080/index.html`. The title bar says "Trame". The main content area has a header "Events and State". Below it, the text "a=10 and b=20" is displayed. There are three buttons: "Reset a", "Reset a & b", and "Reset log". A section titled "Events" contains three buttons: "Reset a", "Reset a & b", and "Reset log". A section titled "States" contains two range inputs for "a" (0-10) and "b" (0-30), and a large text area showing the log history: "Changes to b=2 a=1", "Changes to a=10", and "Changes to b=20". At the bottom, there is a "Start Server" button.

```
39 # Model -----
40 def reset_a():
41     state.a = 10
42
43
44 # View -----
45 with DivLayout(server):
46     html.H1("Events and State")
47
48     html.Div("a={{ a }} and b={{ b }}")
49
50     html.H2("Events")
51
52     html.Button("Reset a", click=reset_a)
53     html.Button("Reset a & b", click="setAll({ b:2, a:1 })")
54     html.Button("Reset log", click="log = ''")
55
56     html.H2("States")
57
58     html.Input(type="range", min=0, max=10, v_model="a")
59     html.Input(type="range", min=0, max=30, v_model="b")
60
61     html.Br()
62
63     html.Textarea(
64         v_model=("log", ""),
65         disabled=True,
66         rows=12,
67         style="width: 15rem;",
68     )
69
70 # Start Server -----
71 server.start()
```

# Hands on (code)

```
$ git clone git@github.com:Kitware/sc25-trame-tutorial.git  
$ cd sc25-trame-tutorial/  
$ uv venv -p 3.10  
$ source .venv/bin/activate  
$ uv pip install trame  
$ python ./code/01-fundamentals/01-state-events.py
```



```
01-fundamentals — Python 01-state-events.py — 98x39  
[~ % git clone git@github.com:Kitware/sc25-trame-tutorial.git -q  
[~ % cd sc25-trame-tutorial/  
~/sc25-trame-tutorial % uv venv -p 3.10  
  
Using CPython 3.10.15 interpreter at: /opt/homebrew/opt/python@3.10/bin/python3.10  
Creating virtual environment at: .venv  
Activate with: source .venv/bin/activate  
[~/sc25-trame-tutorial % source .venv/bin/activate  
(sc25-trame-tutorial) ~/sc25-trame-tutorial % uv pip install trame  
  
Resolved 17 packages in 488ms  
Installed 17 packages in 32ms  
+ aiohappyeyeballs==2.6.1  
+ aiohttp==3.11.16  
+ aiosignal==1.3.2  
+ asyncio-timeout==5.0.1  
+ attrs==25.3.0  
+ frozenlist==1.5.0  
+ idna==3.10  
+ more-itertools==10.6.0  
+ msgpack==1.1.0  
+ multidict==6.2.0  
+ propcache==0.3.1  
+ trame==3.8.1  
+ trame-client==3.7.0  
+ trame-server==3.4.0  
+ typing-extensions==4.13.1  
+ wslink==2.3.3  
+ yarl==1.19.0  
(sc25-trame-tutorial) ~/sc25-trame-tutorial % cd code/01-fundamentals  
(sc25-trame-tutorial) ~/sc25-trame-tutorial/code/01-fundamentals % python 01-state-events.py  
  
App running at:  
- Local: http://localhost:8080/  
- Network: http://127.0.0.1:8080/  
  
Note that for multi-users you need to use and configure a launcher.  
And to prevent your browser from opening, add '--server' to your command line.
```

# Hands on (Jupyter)

```
$ git clone git@github.com:Kitware/sc25-trame-tutorial.git  
$ cd sc25-trame-tutorial/  
$ uv venv -p 3.10  
$ source .venv/bin/activate  
$ uv pip install trame jupyterlab  
$ jupyter lab
```

The screenshot shows a JupyterLab environment with two main panes. The left pane is a code editor displaying Python code for a JupyterLab application. The right pane is a preview area showing the resulting user interface.

**Code Editor Content:**

```
@state.change("log")
def trim_log(log, **_):
    lines = log.split("\n")
    if len(lines) > 10:
        state.log = "\n".join(lines[-10:])

[4]: # Model
def reset_a():
    state.a = 10

[5]: # View
with DivLayout(server) as ui:
    html.H1("Events and State")

    html.Div("a={{ a }} and b={{ b }}")

    html.H2("Events")

    html.Button("Reset a", click=reset_a)
    html.Button("Reset a & b", click=setAll({ b2, a1 }))
    html.Button("Reset log", click="log = ''")

    html.H2("States")

    html.Input(type="range", min=0, max=10, v_model="a")
    html.Input(type="range", min=0, max=30, v_model="b")

    html.Br()

    html.Textarea(
        v_model="log",
        disabled=True,
        rows=12,
        style="width: 15rem;",
    )

[6]: # Show in Jupyter
await ui.ready
ui
```

**Preview Area Content:**

## Events and State

a=4 and b=16

### Events

[Reset a](#) | [Reset a & b](#) | [Reset log](#)

### States

Changes to b=18  
Changes to b=19  
Changes to b=20  
Changes to b=21  
Changes to b=22  
Changes to b=21  
Changes to b=20  
Changes to b=18  
Changes to b=17

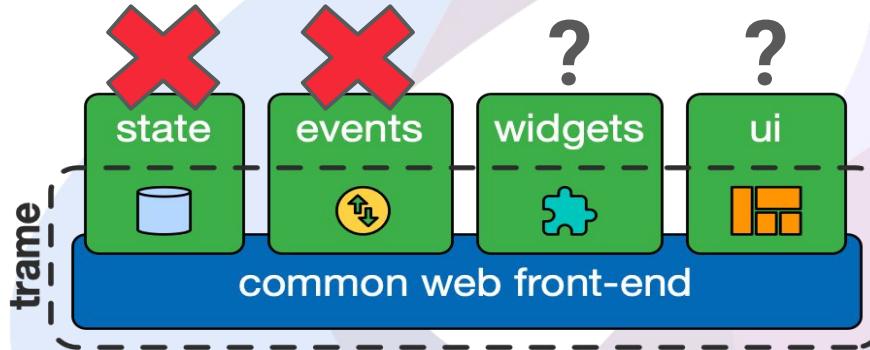
# Fundamentals

- ## Widgets

- Any element that compose the UI.
- This can be an HTML element or a composition of HTML elements.
- i.e. Slider, Button, Plotly figure, VTK 3D view, xTerm, VS Code Editor, Interactive map...

- ## UI

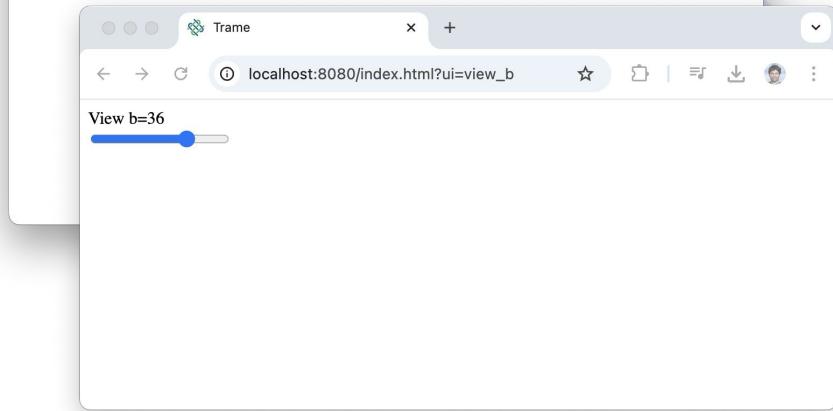
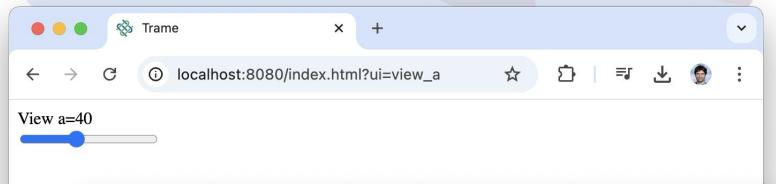
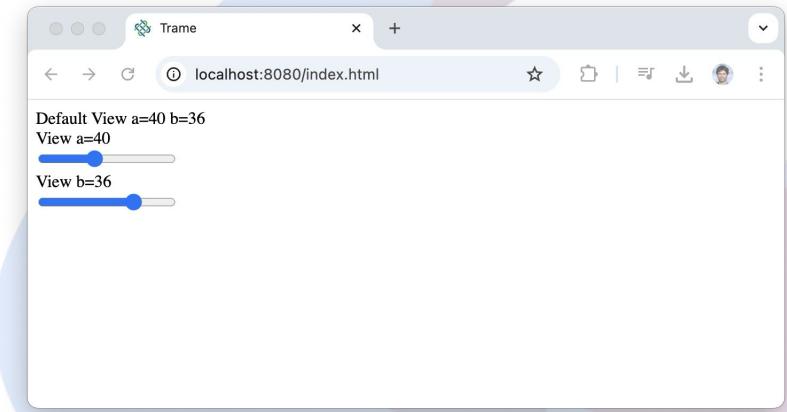
- A root widget or a view containing widgets.
- You can have more than one view/ui.
- A view/ui can be included into another view using the widget `trame.widget.client.ServerTemplate`
- A view can be overridden.



# Hands on (code)

```
1  from trame.app import get_server
2  from trame.widgets import html, client
3  from trame.ui.html import DivLayout
4
5  # Trame setup -----
6
7  server = get_server()
8
9  # View -----
10
11 # Main view
12 with DivLayout(server): # template_name="main"
13     html.Div("Main View a={{a}} b={{b}}")
14     client.ServerTemplate(name="view_a")
15     client.ServerTemplate(name="view_b")
16
17 # view_a
18 with DivLayout(server, template_name="view_a"):
19     html.Div("View a={{a}}")
20     html.Input(
21         type="range",
22         min=0,
23         max=100,
24         step=1,
25         v_model=("a", 0), # Set a default value of 0 to variable "a"
26     )
27
28 # view_b
29 with DivLayout(server, template_name="view_b"):
30     html.Div("View b={{b}}")
31     html.Input(
32         type="range",
33         min=0,
34         max=50,
35         step=2,
36         v_model=("b", 2), # Set a default value of 0 to variable "b"
37     )
38
39 # Start Server -----
40
41 server.start()
```

```
$ python 01-multi-views.py
```



# Hands on (Jupyter)

```
$ jupyter lab
```

```
=> ./jupyter/01-fundamentals/01-multi-views.ipynb
```

The screenshot shows a Jupyter Notebook window titled "02-multi-vie... - auto-5" running at "localhost:8888/lab". The notebook displays a Python script for creating a multi-view application using Trame. The code defines two main views, "view\_a" and "view\_b", each containing a range input for variables "a" and "b". The "view\_main" cell outputs the state of both variables. Below the notebook, two separate browser windows show the resulting Trame application. The first window, labeled "view\_a", shows the value of "a" as 29. The second window, labeled "view\_b", shows the value of "b" as 38. Both windows have sliders for adjusting the variable values.

```
from trame.app import get_server
from trame.widgets import html, client
from trame.ui.html import DivLayout

server = get_server()

# Main view
with DivLayout(server, height=110) as view_main: # template_name="main"
    html.Div("Main View a={a} b={b}")
    client.ServerTemplate(name="view_a")
    client.ServerTemplate(name="view_b")

# view_a
with DivLayout(server, height=50, template_name="view_a") as view_a:
    html.Div("View a={a}")
    html.Input(
        type="range",
        min=0,
        max=100,
        step=1,
        v_model=("a", 0), # Set a default value of 0 to variable "a"
    )

# view_b
with DivLayout(server, height=50, template_name="view_b") as view_b:
    html.Div("View b={b}")
    html.Input(
        type="range",
        min=0,
        max=50,
        step=2,
        v_model=("b", 2), # Set a default value of 0 to variable "b"
    )

[2]: await view_main.ready
view_main

Main View a=29 b=38
View a=29
View b=38

[3]: view_a
View a=29

[4]: view_b
View b=38
```

# Dynamic web interface

Vue.js templating infrastructure

# Trame and its User Interface

- **Vue.js and its HTML template**

An approachable, performant and versatile framework for building web user interfaces.

Vue uses an HTML-based template syntax that allows you to declaratively bind the rendered DOM to the underlying data.

Under the hood, Vue compiles the templates into optimized JavaScript code.

```
with DivLayout(server):
    html.H1("Events and State")

    html.Div("a={{ a }} and b={{ b }}")

    html.H2("Events")

    html.Button("Reset a", click=reset_a)
    html.Button("Reset a & b", click="setAll({ b:2, a:1 })")
    html.Button("Reset log", click="log = ''")

    html.H2("States")

    html.Input(type="range", min=0, max=10, v_model="a")
    html.Input(type="range", min=0, max=30, v_model="b")

    html.Br()

    html.Textarea(
        v_model=("log", ""),
        disabled=True,
        rows=12,
        style="width: 15rem;",
    )
)
```

```
print(layout_or_widget)
```

Converted to vue.js template

```
<div>
  <h1>
    Events and State
  </h1>
  <div>
    a={{ a }} and b={{ b }}
  </div>
  <h2>
    Events
  </h2>
  <button @click="trigger('trigger__1')">
    Reset a
  </button>
  <button @click="setAll({ b:2, a:1 })">
    Reset a & b
  </button>
  <button @click="log = ''">
    Reset log
  </button>
  <h2>
    States
  </h2>
  <input v-model="a" max="10" min="0" type="range" />
  <input v-model="b" max="30" min="0" type="range" />
  <br />
  <textarea style="width: 15rem;" v-model="log" disabled rows="12" />
</div>
```

# What can you do with vue.js templating?

- Text interpolation
- Raw HTML
- Attribute Bindings
- Directives
- Event handling
- JavaScript Expressions

# Text interpolation

Vue.js

```
<label>Hello {{ name }}</label>
```

Trame (Python)

```
html.Label("Hello {{ name }}")
```

\*

```
<SomeWidget  
  :label="`Hello ${name}`"  
/>
```

```
SomeWidget(  
  label=("`Hello ${name}`"),  
)
```

\*see attribute binding + JavaScript expression

# Raw HTML

Vue.js

```
<span v-html="rawHTML"></span>
```

Trame (Python)

```
html.Span(v_html="rawHTML")
```

```
state.rawHTML = ""  
    <label>Hello SC25</label>  
    <p>  
        We are <b>happy</b> to have you here today in this tutorial.  
    </p>  
""
```

# Attribute binding HTML

Mustaches cannot be used inside HTML attributes.

Vue.js

```
<SomeWidget  
  label="Sample code"  
  min="0"  
  
  v-bind:value="a"  
  :style="`color: ${ a > 10 ? 'red' : 'green'};`"  
  v-bind="{ a:1, b:2, c:3 }"  
/>
```

Trame (Python)

```
SomeWidget(  
  label="Sample code",  
  min=0,  
  
  value=("a",),  
  style="...same as JS...",  
  v_bind=("manyProps", dict(...)),  
)
```

\* The tuple expression is to indicate we have a JavaScript expression. Moreover, the second argument of the tuple can be used to assign a default value and reserve that variable name.

\*\* Missing attribute mapping can be added using the `__properties=[("py_name", "vue-name:weird")]` as keyword argument.

# Directives

Directives are special attributes with the **v-** prefix. Vue provides a number of built-in directives, including **v-html** and **v-bind** which we have introduced above. Directive attribute values are expected to be single JavaScript expressions (with the exception of **v-for**, **v-on** and **v-slot**, which will be discussed in their respective sections later). A directive's job is to reactively apply updates to the DOM when the value of its expression changes.

Vue.js

```
<SomeWidget  
  v-if="a > 10"  
  v-show="isVisible"  
  
  v-model="b"  
/>
```

Trame (Python)

```
SomeWidget(  
  v_if="a > 10",  
  v_show="isVisible",  
  
  v_model="b"  
)
```

\*\*No need to use the tuple expression as it is *always* a JavaScript expression, unless we want to assign a default value (and reserve that variable name).

# Event handling

## Vue.js

```
<button  
  v-on:click="doSomething"  
>Click Me</button>
```

```
<button  
  @click="doSomething"  
>Click Me</button>
```

## Trame (Python)

```
html.Button(  
  "Click Me",  
  click="doSomething",  
)
```

\* Trame do not show any difference between an attribute or an event.

\*\* Modifiers can be added to the event (**stop**, **prevent...**) [**@click.prevent=** / **click\_prevent=**]

\*\*\* Events mapping can be missing in trame but could be added using the

**\_\_events=[("click\_prevent\_stop", "click.prevent.stop")]** keyword arg.

# JavaScript expressions

- ## String templating

```
<b>static {{ dynamic }}</b>
```

```
<b>
  static
  {{ message.split(' ').reverse().join(' ') }}
</b>
```

```
<widget :label="`static ${dynamic}`" />
```

- ## Ternary evaluation

```
<b>static {{ ok ? 'yes' : 'no' }}</b>
```

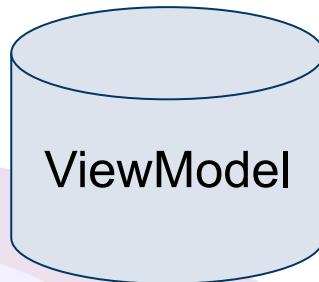
```
<widget :label="`static ${ok ? 'yes' : 'no'}`" />
```

- ## Conditions

```
a && b || c || d === e || f == g || h > 3 || array.includes(search) || obj?.a?.c?.[6]
```

# State handling cheat sheet

```
from trame.app import get_server  
server = get_server()  
state = server.state
```



```
@state.change("a", "b", "c")  
def change_detected(a, b, c, d, **kwargs):  
    pass  
  
state.a = 10  
print(f"a={state.a}")  
  
def update_var(name, value)  
    print(f"Before: {name}={state[name]}")  
    state[name] = value  
    print(f"After: {name}={state[name]}")
```

Widget(key="welcome") : Use string 'welcome'  
Widget(key=("welcome",)) : Evaluate expression 'welcome'  
Widget(key=("welcome", "Hello")) : Evaluate expression 'welcome' and initialize it to "Hello"

JS

# Event handling cheat sheet

```
from trame.app import get_server  
server = get_server()  
ctrl = server.controller
```

```
# @ctrl.set("hello_alias")  
def hello(*args, **kwargs):  
    print(args, kwargs)
```

```
@ctrl.add("hello_alias")  
def hello2(*args, **kwargs):  
    print("v2:", args, kwargs)
```

```
ctrl.hello_alias = hello  
ctrl.hello_alias('arg_0', key='yes')
```

Event / Method calls

JS

VBtn(click="js\_fn")

: Call the JS code

VBtn(click=fn)

: Call the function with no args

VBtn(click=(fn, "[1, \$event, 'hello']"))

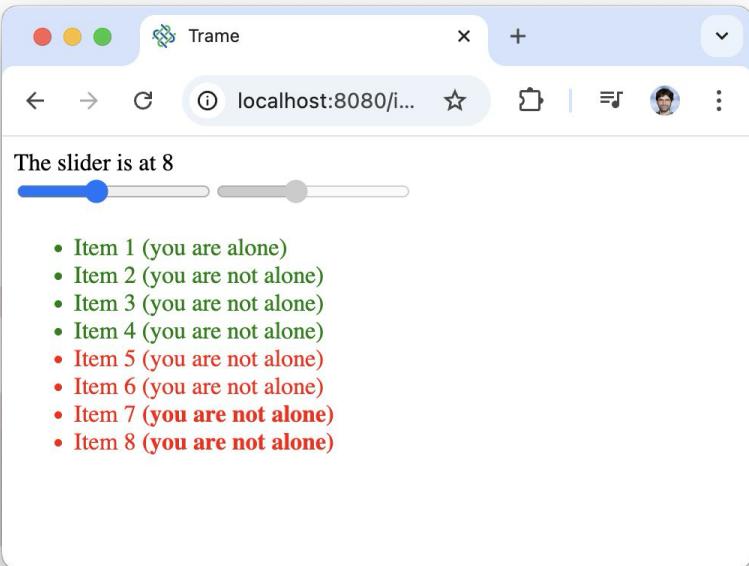
: Call the function like fn(1, event, "hello")

VBtn(click=(fn, "[{\$event}]", "{ x: 5 }"))

: Call the function like fn(event, x=5)

# Hands on (code)

```
$ python ./code/02-dynamic-ui/01-directives.py
```



```
# Reactivity
@state.change("a")
def update_b(a, *_):
    state.ul_li_list = [f"Item {i + 1}" for i in range(int(a))]

# View -----
# Main view
with DivLayout(server):
    html.Div("The slider is at {{ a }}")
    html.Input(
        type="range",
        min=0,
        max=20,
        step=1,
        v_model=("a", 0), # Set a default value of 0 to variable "a"
    )
    html.Input(
        type="range",
        min=0,
        max=20,
        step=1,
        value=(a,), # property v-model bind (:modelValue + @update:modelValue
        disabled=True,
    )
    with html.Ul():
        with html.Li(
            "{{ name }}",
            key="idx",
            v_for="name, idx in ul_li_list",
            style="{'color': idx > 3 ? 'red' : 'green'}",
        ):
            html.Span(
                "(you are not alone)",
                v_if="idx > 0",
                style="{'font-weight': $idx > 5 ? 'bold' : 'normal'}",
            )
            html.Span("(you are alone)", v_else=True)
```

# Hands on (Jupyter)

```
$ jupyter lab
```

```
=> ./jupyter/02-dynamic-ui/01-directives.ipynb
```

The screenshot shows a Jupyter Notebook interface with two panes. The left pane displays the code for a notebook named '01-directives.ipynb'. The right pane shows the resulting output, which includes a Python code block, a range input slider, and a list of items.

```
from trame.app import get_server
from trame.widgets import html
from trame.ui.html import DivLayout

server = get_server()

state = server.state

@state.change("a")
def update_b(a, **_):
    state.ul_li_list = [f"Item {i + 1}" for i in range(int(a))]

with DivLayout(server, height=300) as ui:
    html.Div("The slider is at {{ a }}")
    html.Input(
        type="range",
        min=0,
        max=20,
        step=1,
        v_model="a", 0, # Set a default value of 0 to variable "a"
    )
    html.Input(
        type="range",
        min=0,
        max=20,
        step=1,
        value="a", # property v-model bind (:modelValue + @update:modelValue || :value + @input)
        disabled=True,
    )
    with html.Ul():
        with html.Li(
            "{{ name }}",
            key="idx",
            v_for="name, idx in ul_li_list",
            style="color: idx > 3 ? 'red' : 'green' ;",
        ):
            html.Span(
                "(you are not alone)",
                v_if="idx > 8",
                style="font-weight: ${idx > 5 ? 'bold' : 'normal'};",
            )
            html.Span("you are alone", v_else=True)
await ui.ready
ui
```

The slider is at 11

- Item 1 (you are alone)
- Item 2 (you are not alone)
- Item 3 (you are not alone)
- Item 4 (you are not alone)
- Item 5 (you are not alone)
- Item 6 (you are not alone)
- Item 7 (you are not alone)
- Item 8 (you are not alone)
- Item 9 (you are not alone)
- Item 10 (you are not alone)
- Item 11 (you are not alone)

# Vuetify for beautiful UI

From playground to trame user interface

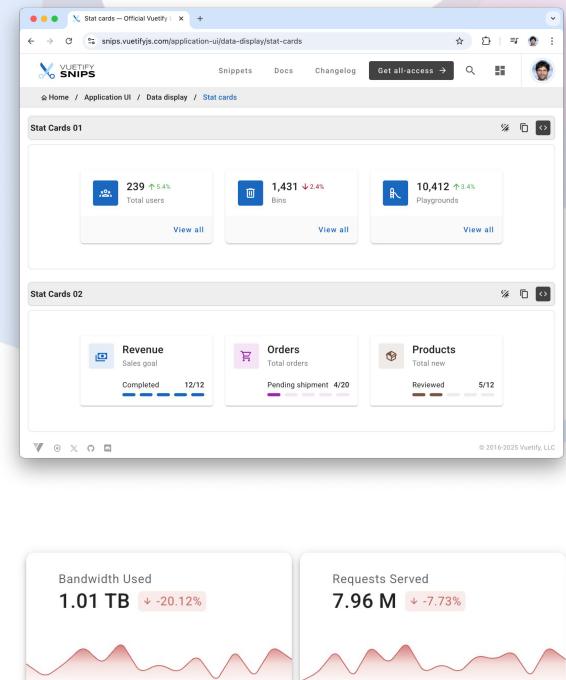
# From basic to pretty with Vuetify

Vue.js App.vue

```
1 <template>
2   <v-layout>
3     <v-navigation-drawer v-model="drawer" width="280">
4       <div class="d-flex align-center pa-4">
5         
6         <div class="text-h6 font-weight-medium">Vuetify.com</div>
7       </div>
8       <v-list-item>
9         <v-list-item-action>
10          
11        <div class="text-h4 py-2">
12          <v-text-field>
13            <v-select surface-light color="primary" density="compact" hide-details placeholder="Search" prepend-inner-icon="mdi-magnify" rounded="lg" variant="outlined" />
14        </div>
15      </v-list-item>
16    </v-navigation-drawer>
17    <div class="flex-grow-1">
18      <v-app-bar>
19        <v-toolbar>
20          <v-btn icon="mdi-menu" @click="drawer = !drawer" />
21          <v-toolbar-title>Vuetify Application</v-toolbar-title>
22          <v-spacer/>
23          <v-btn icon="mdi-dash" @click="openDashboard" />
24        </v-toolbar>
25        <v-card>
26          <v-card-item>
27            <v-list density="comfortable" nav slim>
28              <v-list-subheader class="font-weight-bold">FAVORITES</v-list-subheader>
29              <v-list-item v-for="item, index in favorites" :key="index">
30                <v-list-item-action>
31                  
32                  <div>
33                    <span>{{ item.title }}</span>
34                    <span>{{ item.value }}</span>
35                  </div>
36                </v-list-item-action>
37                <div>
38                  <v-list-item-content>
39                    <v-form px-2>
40                      <v-badge color="error" content="item.badge" inline />
41                    </v-form>
42                  </v-list-item-content>
43                </div>
44              </v-list-item>
45            <v-list density="comfortable" nav slim>
46              <v-list-subheader class="font-weight-bold">APPLICATION</v-list-subheader>
47              <v-list-item v-for="item, index in applications" :key="index">
48                <v-list-item-action>
49                  
50                  <div>
51                    <span>{{ item.title }}</span>
52                    <span>{{ item.value }}</span>
53                  </div>
54                </v-list-item-action>
55                <div>
56                  <v-list-item-content>
57                    <v-form px-2>
58                      <v-badge color="error" content="item.badge" inline />
59                    </v-form>
60                  </v-list-item-content>
61                </div>
62              </v-list-item>
63            </v-list>
64          </v-card-item>
65        </v-card>
66      </v-app-bar>
67      <v-main>
68        <v-container fluid>
69          <v-row>
70            <v-col>
71              <div>
72                <h3>John Leider ★</h3>
73                <div>333 FOLLOWERS 26 PROJECTS 17 COLLECTIONS 130 SHOTS</div>
74                <div>
75                  <div>Total subscribers 23,412</div>
76                  <div>Total revenue $14,301</div>
77                  <div>Total orders 402</div>
78                  <div>Total products 76</div>
79                </div>
80                <h4>Upcoming Events</h4>
81                <v-list density="comfortable" nav>
82                  <v-list-item>
83                    <v-list-item-content>
84                      <div>20 FRI</div>
85                      <div>Meeting for campaign with sales team</div>
86                      <div>31+</div>
87                    </v-list-item-content>
88                  </v-list-item>
89                  <v-list-item>
90                    <v-list-item-content>
91                      <div>22 SUN</div>
92                      <div>Product Review Meeting</div>
93                      <div>27+</div>
94                    </v-list-item-content>
95                  </v-list-item>
96                  <v-list-item>
97                    <v-list-item-content>
98                      <div>25 THU</div>
99                      <div>Team Sync-up</div>
100                     <div>15+</div>
101                   </v-list-item-content>
102                 </v-list-item>
103               </v-list>
104             </div>
105             <div>
106               <div>Product Review Meeting</div>
107               <div>January 22, 2024</div>
108               <div>Review of new product features</div>
109             </div>
110             <div>
111               <div>Team Sync-up</div>
112               <div>January 25, 2024</div>
113               <div>Weekly team synchronization meeting</div>
114             </div>
115           </div>
116         </v-row>
117       </v-container>
118     </v-main>
119   </div>
120 </v-app>
```

Snippets

Cloud Intelligence™ — Cut waste, not performance. Discover where costs add up — and how to optimize.



# Explore components and options

The screenshot shows the Vuetify.js documentation page for the `v-card` component. The left sidebar has a red dashed box around the `Cards` section. The main content area shows the `v-card` component usage with three tabs: `Default`, `Outlined`, and `Tonal`. A blue arrow points from the sidebar's `Cards` link to the `Default` tab. To the right, a sidebar titled "Contents" lists various component options like `Usage`, `Props`, and `Slots`. A red dashed box highlights the `Props` section, which contains checkboxes for `Show title`, `Show subtitle`, `Show actions`, and `Loading`. A blue arrow points from the sidebar's `Props` link to the `Show title` checkbox. Below the component preview, a black box contains the template code:

```
<v-card title="Card title" subtitle="Subtitle" text="..."></v-card>
```

Select component

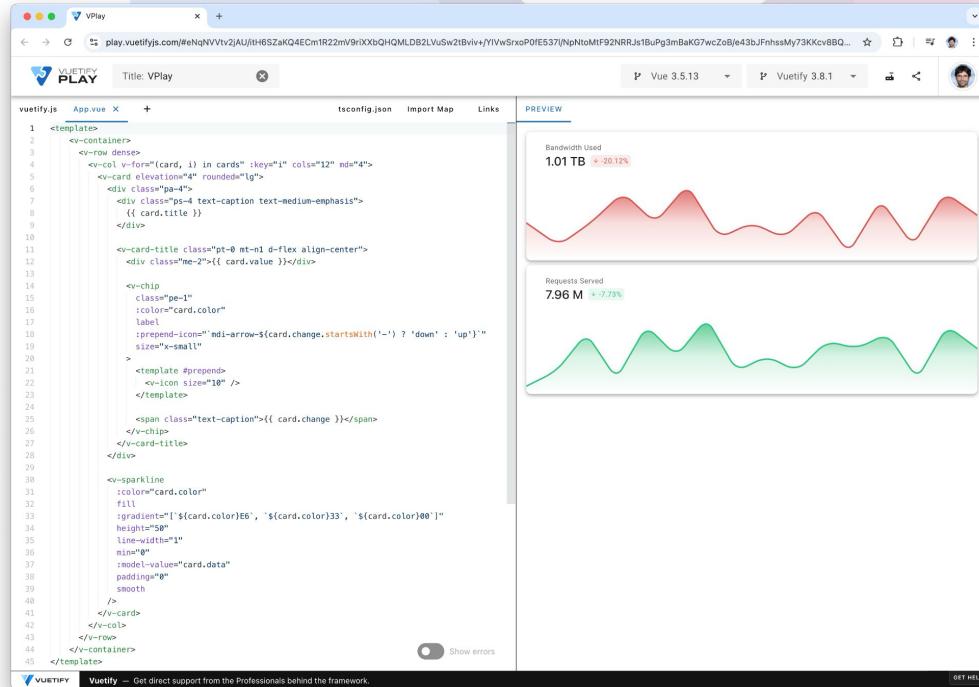
Preview

Options

Template code

# Using the playground to design UI

- Hands on in
- Open `./code/03-vuetify/App.vue`
- Paste it inside the playground
- Try editing or adding other widgets from vuetify



The screenshot shows the Vuetify Playground interface. On the left, the code editor displays `vuetify.js` and `App.vue`. The `App.vue` template includes components like `<v-form>`, `<v-card>`, `<v-chip>`, and `<sparkline>`. The right side features a "PREVIEW" tab showing a live visualization of two data series: "Bandwidth Used" (red line) and "Requests Served" (green line).

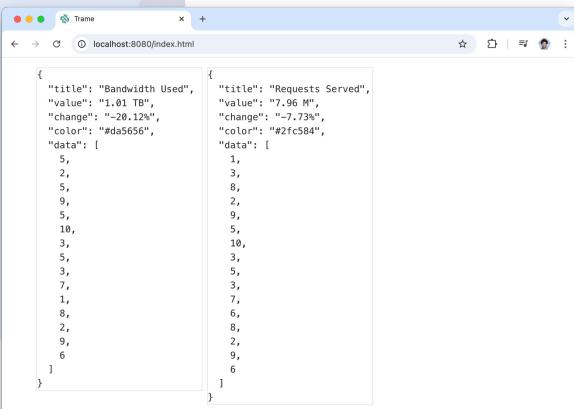
```
1  <template>
2    <v-container>
3      <v-row dense>
4        <v-col v-for="(card, i) in cards" :key="i" cols="12" nd="4">
5          <v-card elevation="4" rounded="lg">
6            <div class="pa-4">
7              <div class="ps-4 text-caption text-medium-emphasis">
8                {{ card.title }}
9              </div>
10             <v-card-title class="pt-0 mt-1 d-flex align-center">
11               <div class="me-2">{{ card.value }}</div>
12
13               <v-chip
14                 class="pe-1"
15                 color="card.color"
16                 label="Change"
17                 :prepend-icon="mdiArrowUpIfChange"
18                 :prepend-icon="mdiArrowDownIfChange"
19                 size="small"
20               >
21                 <template #prepend>
22                   <v-icon size="18px" />
23                 </template>
24
25                 <span class="text-caption">{{ card.change }}</span>
26               </v-chip>
27             </v-card-title>
28           </div>
29
30           <sparkline
31             color="card.color"
32             fill
33             gradient="['${card.color}@0', '${(card.color)33}', '${(card.color)66}'"
34             height="50px"
35             line-width="1px"
36             nine="0"
37             model-values="card.data"
38             padding="8px"
39             smooth
40             />
41         </v-card>
42       </v-col>
43     </v-row>
44   </v-container>
45 </template>
```

# From the playground to trame

- Hands on in
- uv pip install **trame-vuetify**
- Edit **./code/03-vuetify/01-static-card-edit.py**
- Reproduce your playground template in Python

```
state.cards = [
    {
        "title": "Bandwidth Used",
        "value": "1.01 TB",
        "change": "-20.12%",
        "color": "#da5656",
        "data": [5, 2, 5, 9, 5, 10, 3, 5, 3, 7, 1, 8, 2, 9, 6],
    },
    {
        "title": "Requests Served",
        "value": "7.96 M",
        "change": "-7.73%",
        "color": "#2fc584",
        "data": [1, 3, 8, 2, 9, 5, 10, 3, 5, 3, 7, 6, 8, 2, 9, 6],
    },
]

# View -----
with VAppLayout(server):
    with v3.VContainer():
        with v3.VRow(dense=True):
            with v3.VCol(v_for="(card, i) in cards", key="i", cols=12, md=4):
                html.Pre("{{ JSON.stringify(card, null, 2) }}", classes="border-thin")
                # Use App.vue template content and convert it to Python
```

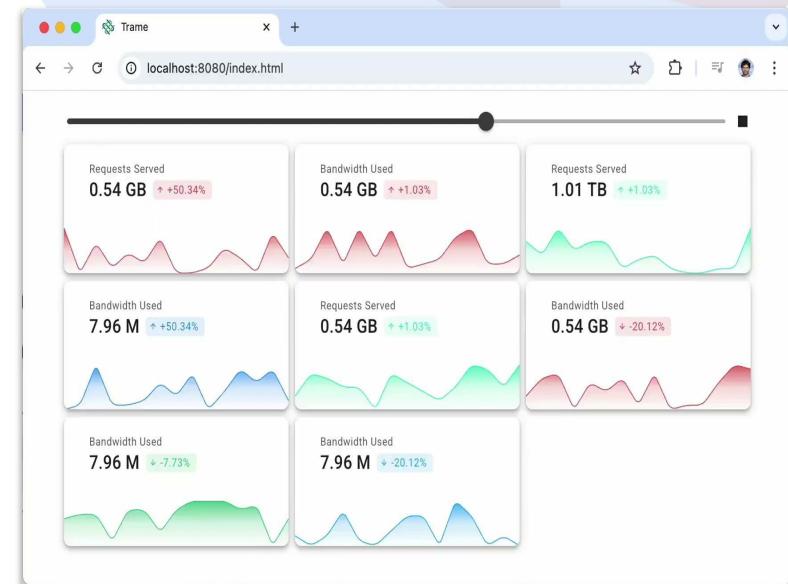
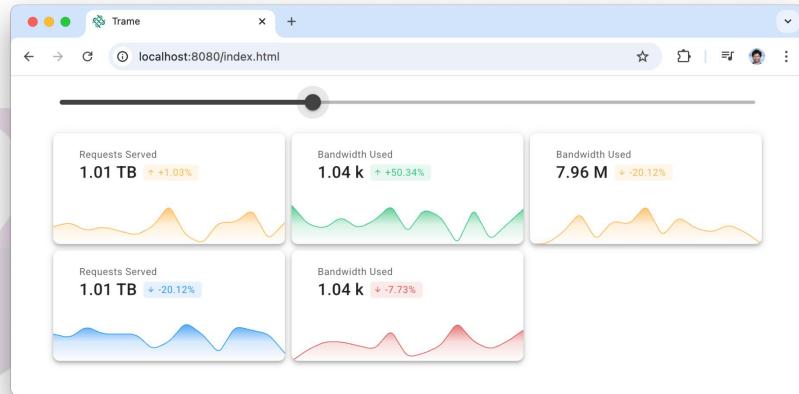


```
{
    "title": "Bandwidth Used",
    "value": "1.01 TB",
    "change": "-20.12%",
    "color": "#da5656",
    "data": [
        5,
        2,
        5,
        9,
        5,
        10,
        3,
        5,
        3,
        7,
        1,
        8,
        2,
        9,
        6
    ]
},
{
    "title": "Requests Served",
    "value": "7.96 M",
    "change": "-7.73%",
    "color": "#2fc584",
    "data": [
        1,
        3,
        8,
        2,
        9,
        5,
        10,
        3,
        5,
        3,
        7,
        6,
        8,
        2,
        9,
        6
    ]
}
```



# Beautiful dynamic UI

- Hands on in
- Run `./code/03-vuetify/03-dynamic-cards.py`
- Run `./code/03-vuetify/04-animation.py`



# COFFEE BREAK



# 3D Visualization

Using VTK or ParaView for your visualization

# Let's start with a VTK example

- Install more libraries (VTK)

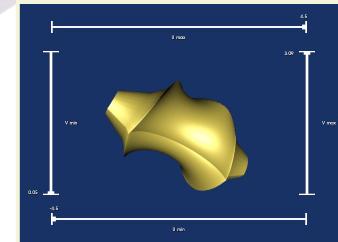
```
$ uv pip install vtk trame-vtk
```

- Use existing code from VTK example Website

<https://examples.vtk.org/site/Python/GeometricObjects/ParametricKuenDemo/>

- Convert it to a trame application with Vuetify

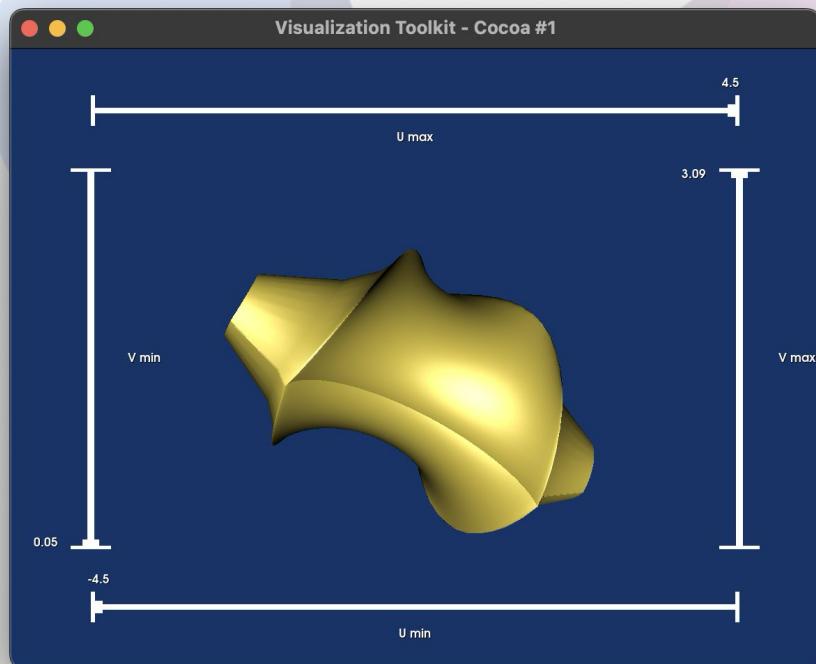
Use *trame.ui.SinglePageLayout + widgets.vuetify3.VRangeSlider*.



# Hands on (code) - vtk example

```
$ uv pip install vtk trame-vtk  
$ python ./code/04-visualization-3d/01-vtk-example.py
```

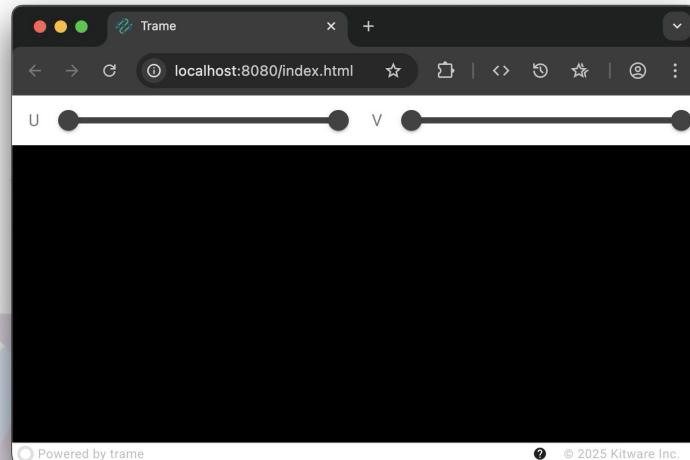
Screenshot of a web browser showing the [ParametricKuenDemo](https://examples.vtk.org/site/Python/GeometricObjects/ParametricKuenDemo) page from the vtk-examples repository. The page displays a 3D visualization of a Kuen surface, a surface of constant Gaussian curvature  $K = -1$ . The visualization includes a coordinate system with axes labeled U, V, and W. The U-axis ranges from -4.5 to 4.5, the V-axis from -4.5 to 3.09, and the W-axis from 0.05 to -4.5. The surface is rendered in yellow.



# Hands on (code) - make it trame

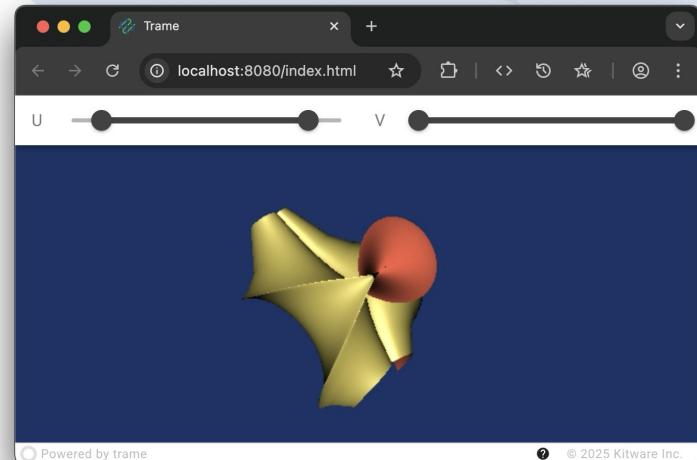
Edit `./code/04-visualization-3d/02-vtk-trame-edit.py`

```
$ python ./code/04-visualization-3d/02-vtk-trame-edit.py  
$ python ./code/04-visualization-3d/03-vtk-trame-solution.py
```



45% smaller  
than pure  
VTK

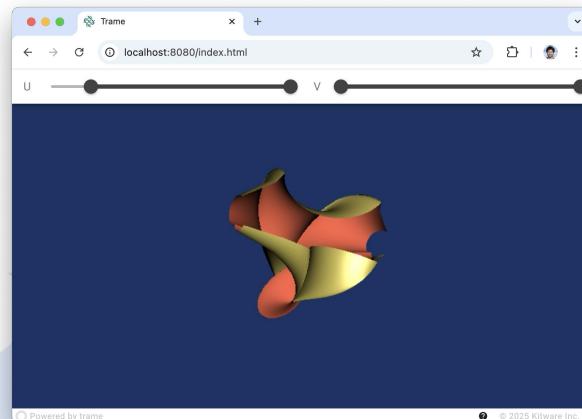
→  
From 250  
lines to 137



# Hands on (code) - remote/local rendering

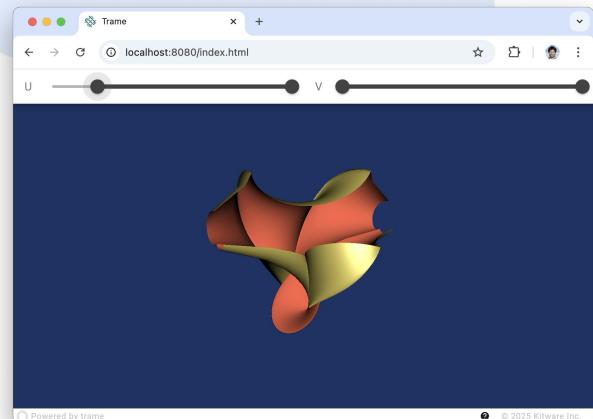
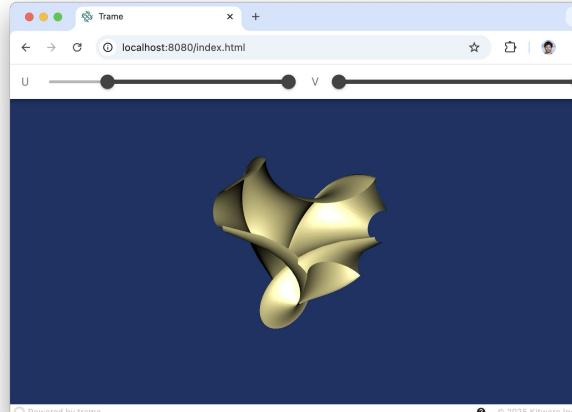
```
$ uv pip install trame-vtklocal
```

```
$ python ./code/04-visualization-3d/04-vtk-trame-remote.py  
$ python ./code/04-visualization-3d/04-vtk-trame-local-js.py  
$ python ./code/04-visualization-3d/04-vtk-trame-local-wasm.py
```



VTK - Remote

vtk.js - Local



VTK.wasm - Local

# Hands on (code) - ParaView

- Need a venv compatible with ParaView

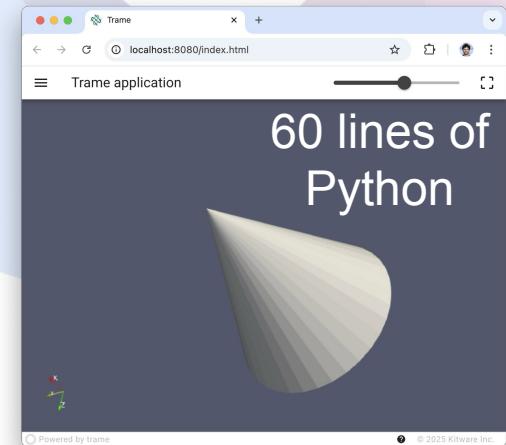
```
$ uv venv -p 3.10
```

```
$ source .venv/bin/activate
```

```
$ pip install trame trame-vtk trame-vuetify
```

- Running the application

```
$ pypython --venv .venv ./code/04-visualization-3d/05-paraview-cone.py
```



# Hands on (code) - ParaView with MPI

- Running the application

```
$ pvpython --venv .venv ./code/04-visualization-3d/06-paraview-mpi.py
```

```
$ mpiexec -n 4 pvbatch --venv .venv ./code/04-visualization-3d/06-paraview-mpi.py
```



!!! mac ARM - have a hanging issue with ParaView/MPI

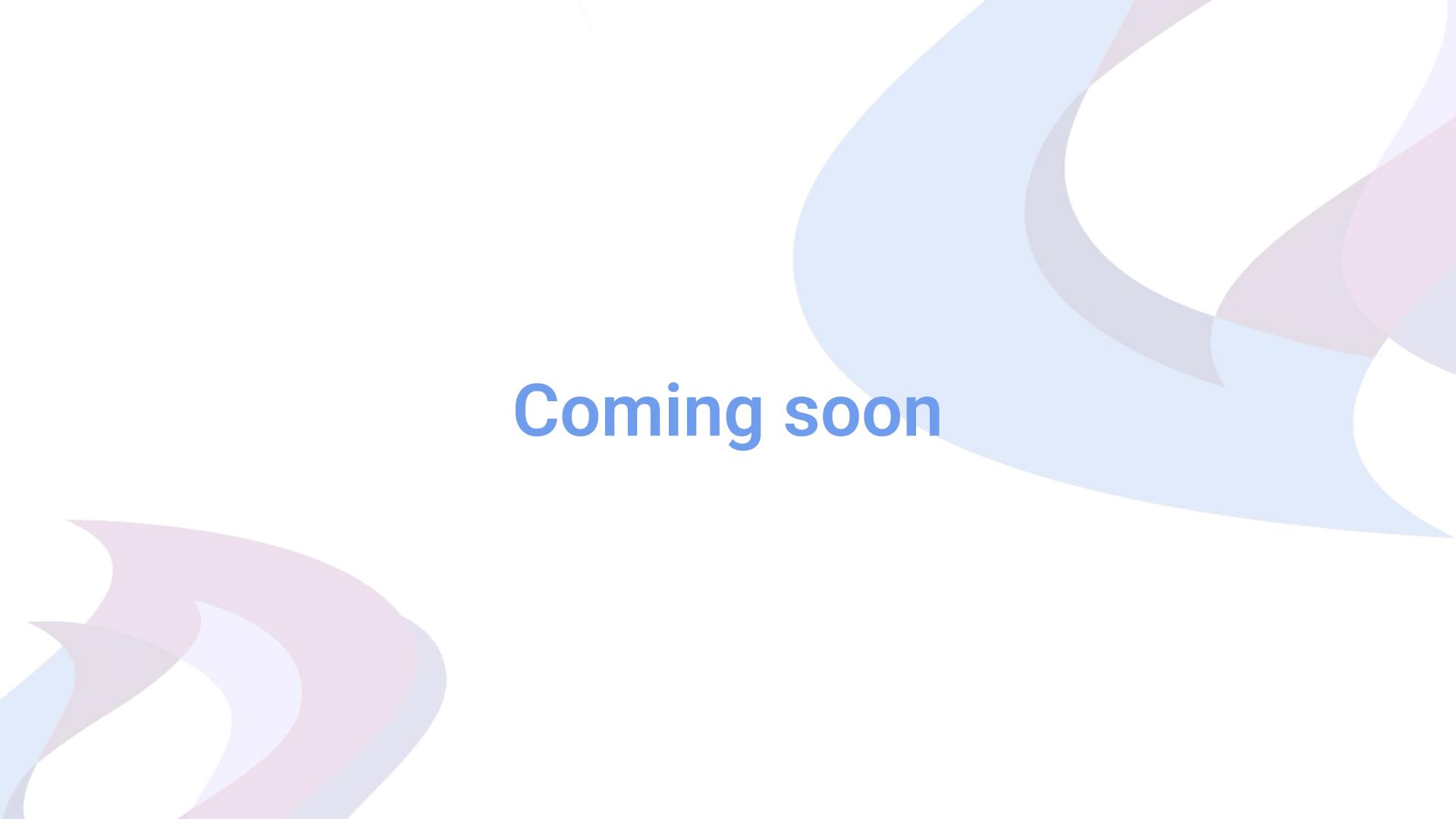
# Charts

Using matplotlib, plotly or altair

Coming soon

# Interactive data processing

Better data exploration with interactive processing



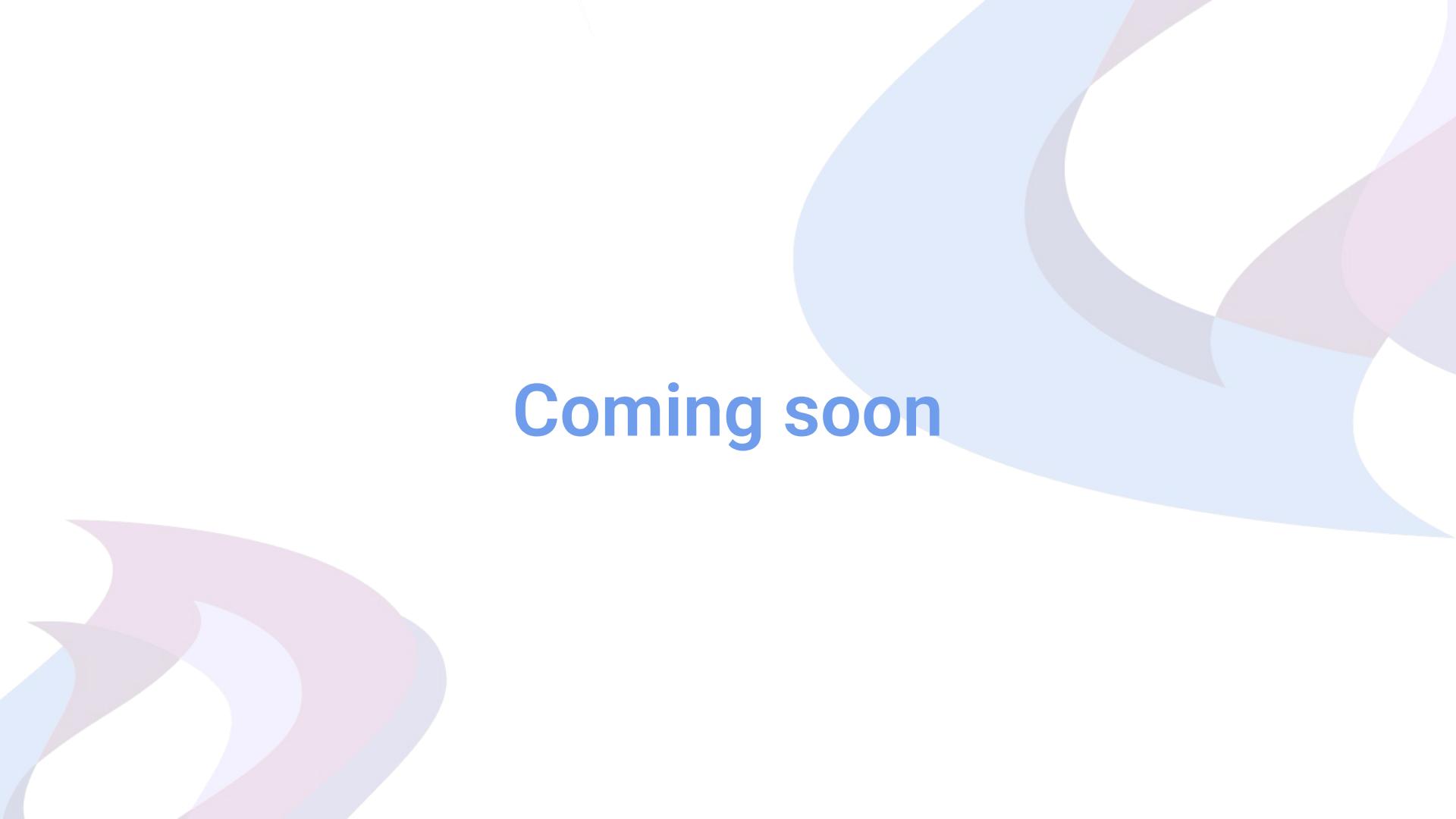
Coming soon

LUNCH  
BREAK



# Peacock 2.0

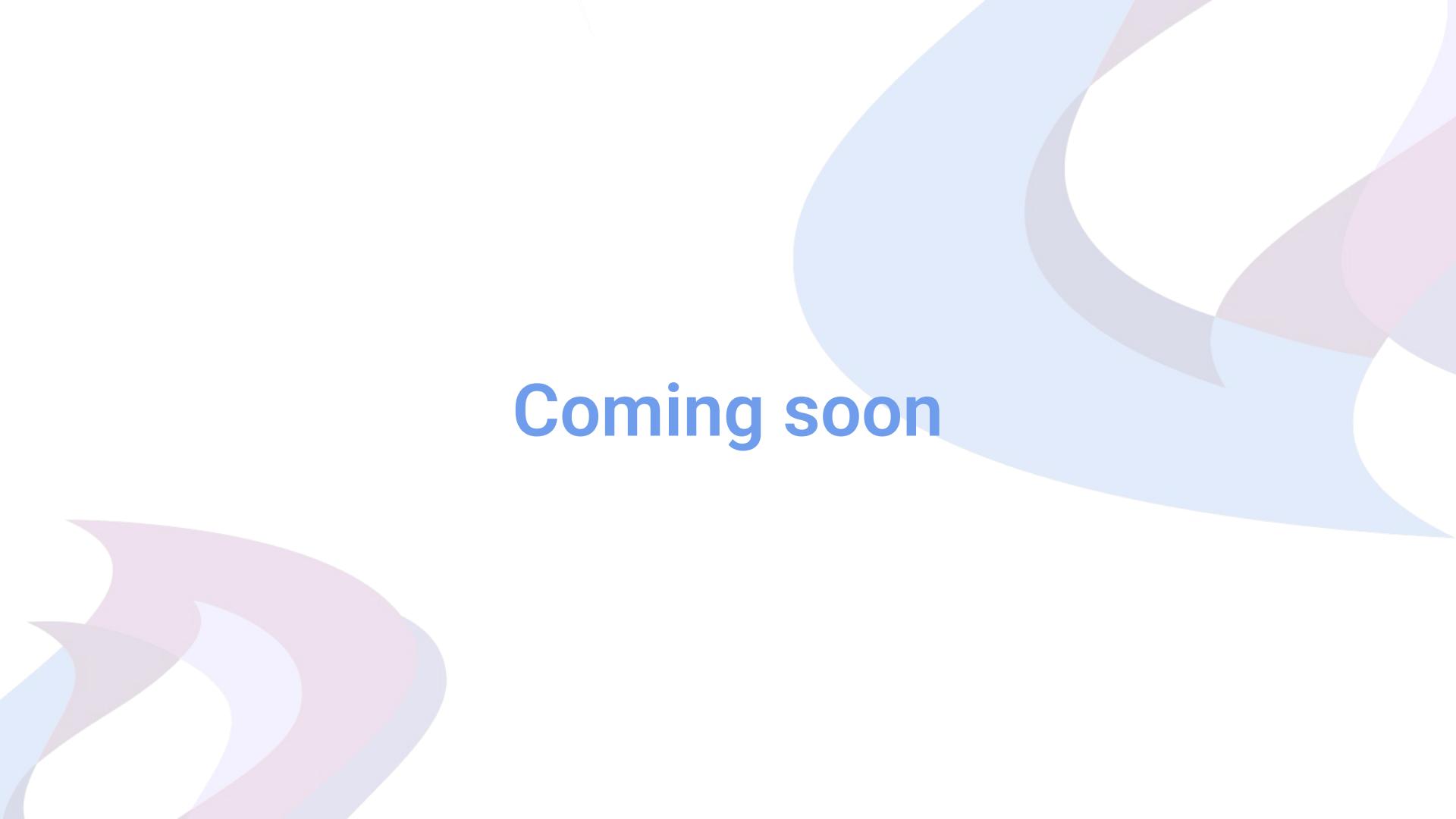
Logan Harbour (Idaho National Lab)



Coming soon

# **Building Interactive Dashboards for the Beam, Plasma & Accelerator Simulation Toolkit (BLAST) with trame**

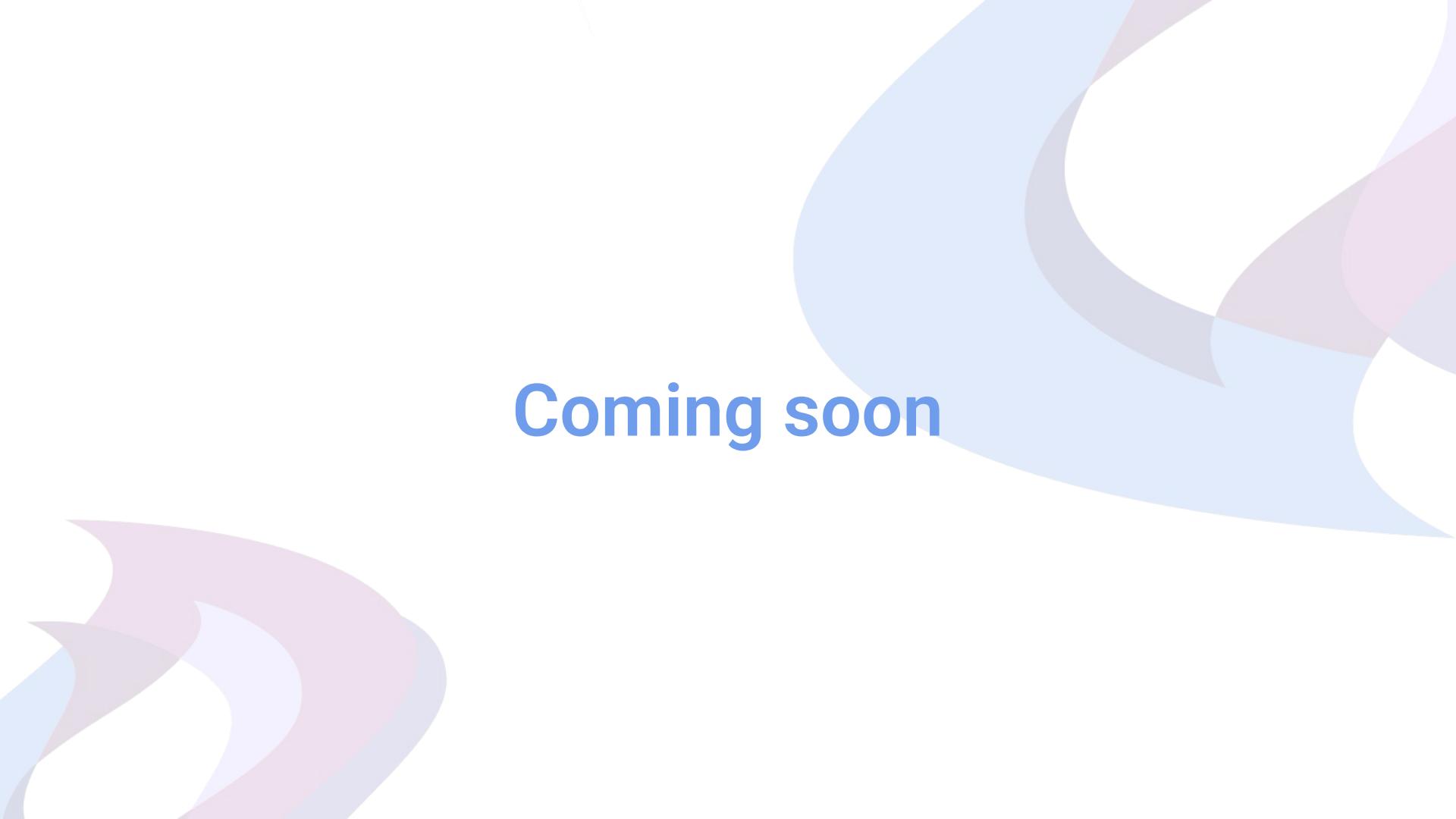
Axel Huebl (Lawrence Berkeley National Lab)



Coming soon

# **Skip the process bloat and run your CFD anywhere with M-Star & trame**

Brian DeVincentis (M-Star)



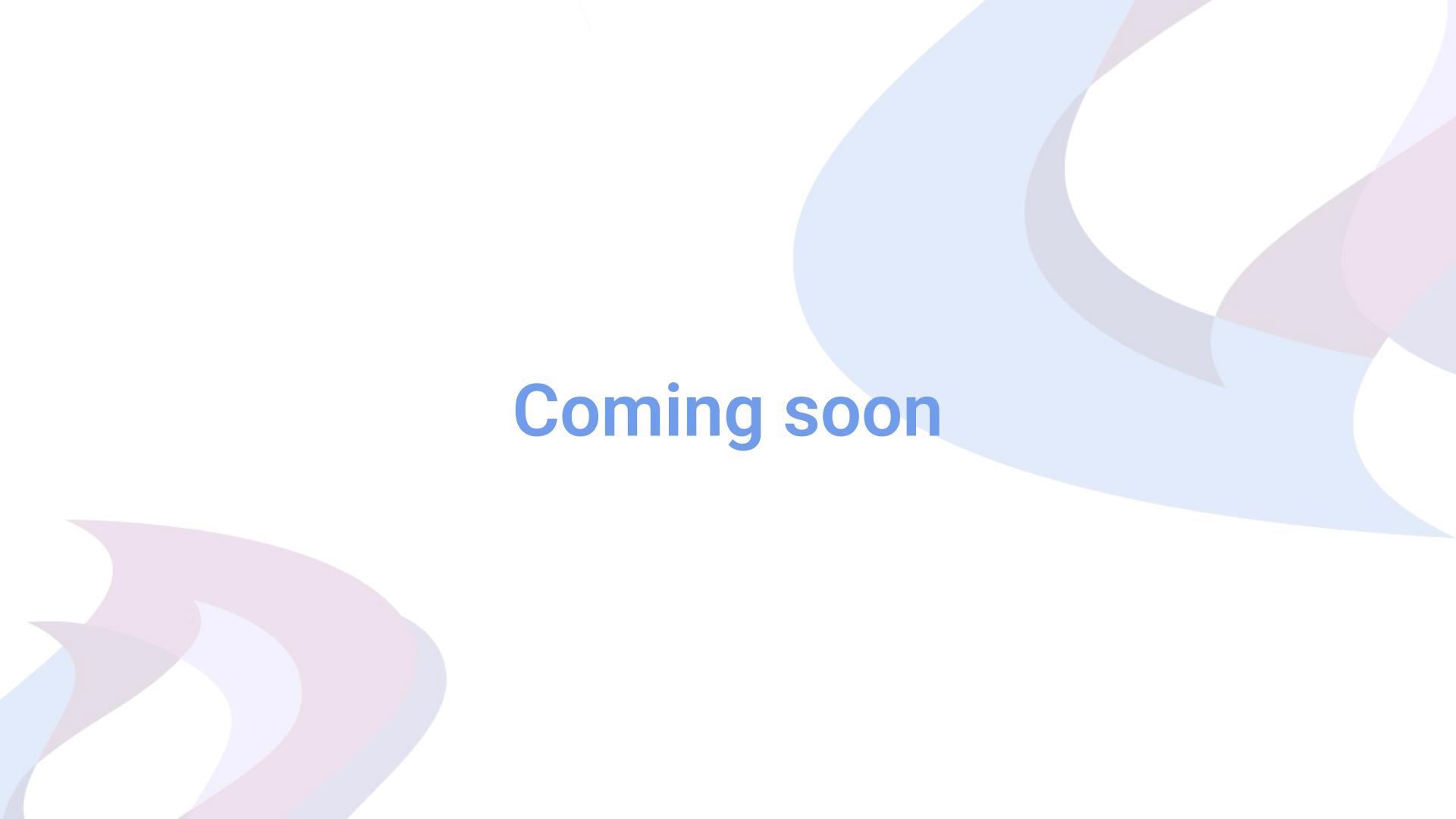
Coming soon

# COFFEE BREAK



# Genomic visualization at scale with ParaView and trame

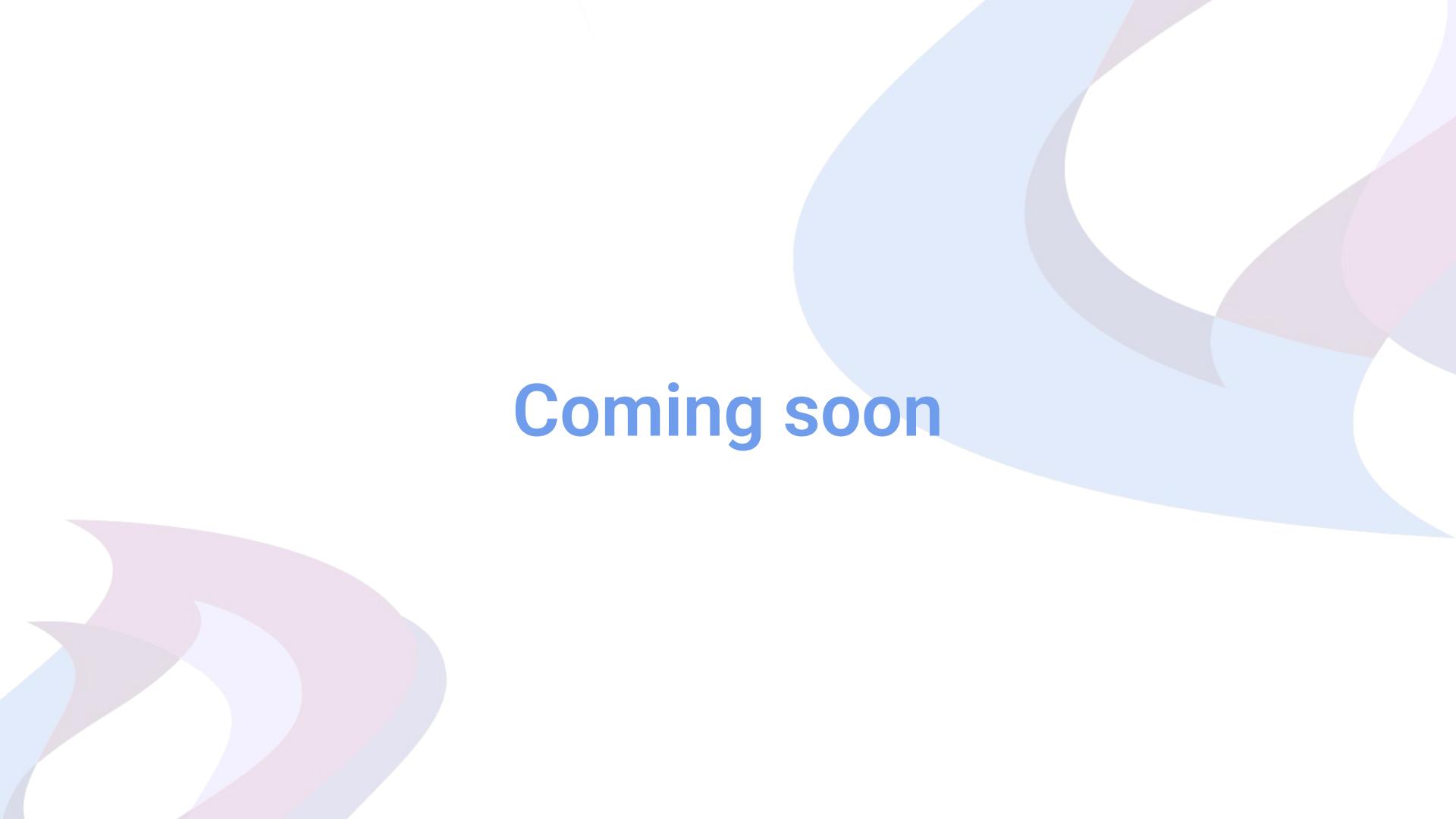
David Rogers (Los Alamos National Lab)



Coming soon

# Real-Time Simulation Control and Visualization through trame

Victor Mateevitsi (Argonne National Lab)



Coming soon

# Natural Robustness Testing and Model Explainability for AI Test and Evaluation

Sebastien Jourdain (Kitware)

Disclaimer: This material is based upon effort sponsored by the U.S. Government under the Tradewind Project Agreement. The U.S. Government is authorized to reproduce and distribute reprints for Governmental purposes notwithstanding any copyright notation thereon. The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of the U.S. Government.

# Kitware is known for ParaView, but we do so much more...



Multimodal Large Language Models

Generative AI

Dataset Collection and Annotation

Cyber Physical Systems (CPS)

Computational Imaging

AI Test, Evaluation, and Assurance

Activity, Threat, and Anomaly Detection

Tracking

Combatting Disinformation

Object Detection and Classification

3D Reconstruction, Point Clouds, and Odometry

Explainable and Ethical AI

Interactive AI and Human Machine Teaming

Space

Air

Land

Sea Surface

Undersea

Open Source Toolkits

VIAME

XAITK

GeoWATCH

TeleSculptor

KWIVE R

SMQTK

SMQT K

LidarView

60+ team members  
24 PhDs  
40+ cleared  
40+ active projects  
Vision-ary since 2007

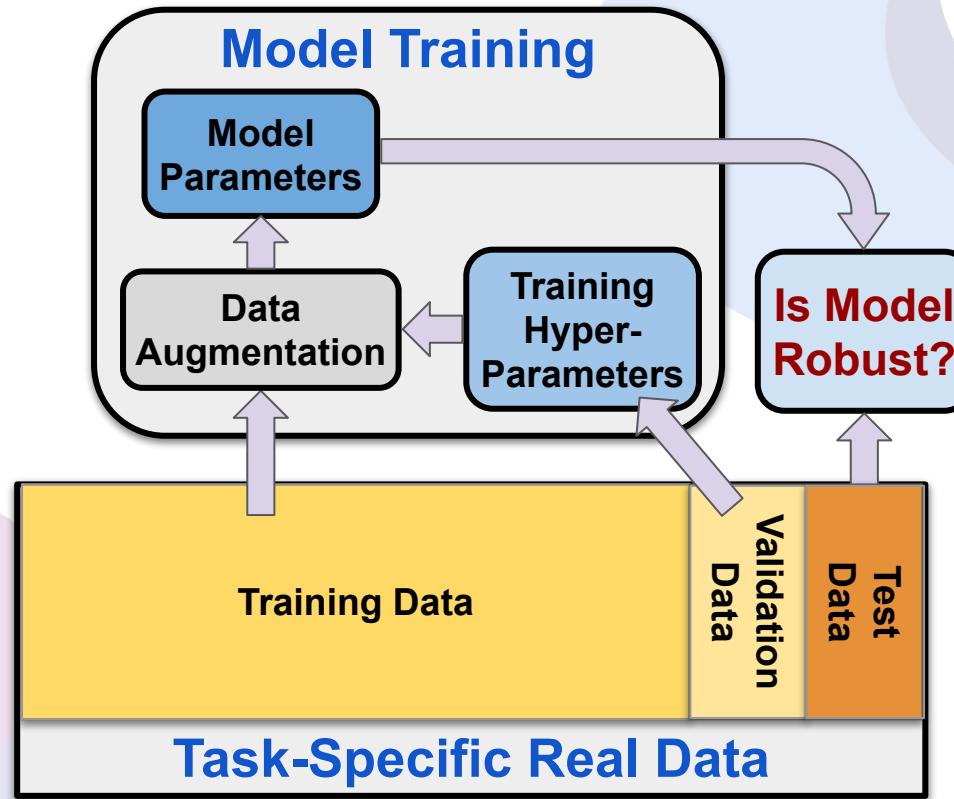
**Kitware**  
Delivering Innovation

# Under CDAO JATIC (Joint AI Test Infrastructure Capability)

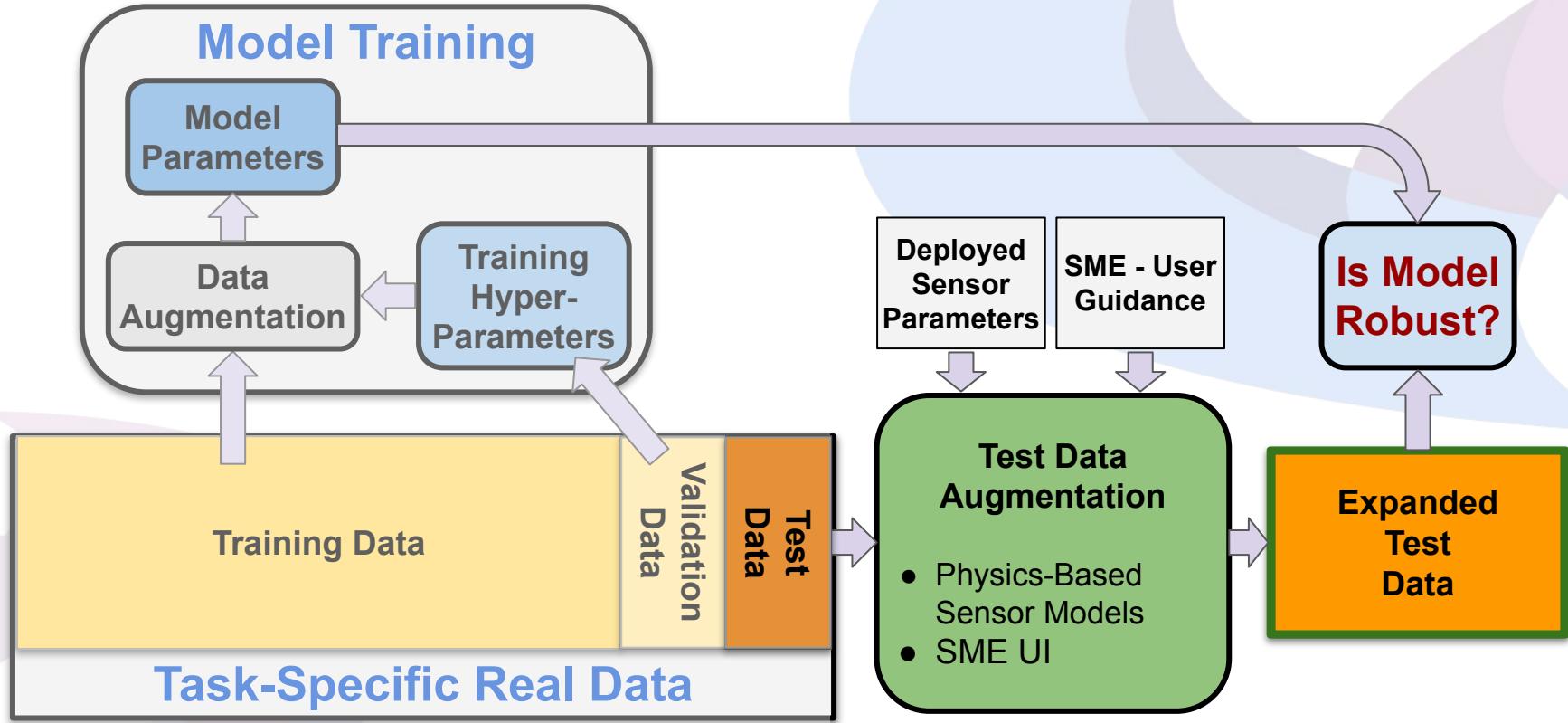
## Kitware is focusing on 2 Open Source projects

- **Natural Robustness Toolkit (NRTK)**
  - Evaluate models against physics-based, operationally-realistic perturbations
- **Explainable AI Toolkit (XAITK)**
  - Generate visual saliency maps on AI predictions using black-box and white-box techniques

# Existing AI Test and Evaluation Approach



# Robust AI Test and Evaluation Approach



# Natural Robustness Toolkit (NRTK)

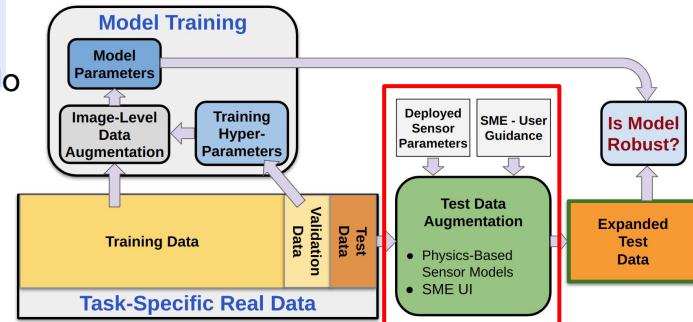
**Natural Robustness Toolkit (NRTK)** is a platform for generating validated, sensor-specific perturbations and transformations used to evaluate the robustness of computer vision models

## Background

- Computer vision models are sensitive to data distribution shifts (either due to synthetic image perturbations or those naturally occurring in real data)
- Existing image augmentation libraries (e.g. [imgaug](#), [albumentations](#)) do not cover physics-based, sensor-specific perturbations that are relevant to operational data

## NRTK Use Cases

- Assess robustness of computer vision models trained on satellite images to changes in different sensor parameters (e.g. focal length, aperture, pixel pitch, etc)
- Develop validated sets of sensor perturbation parameters and expanded datasets for comprehensive model test and evaluation (T&E)



*NRTK expands existing datasets to enable more robust test and evaluation of models*

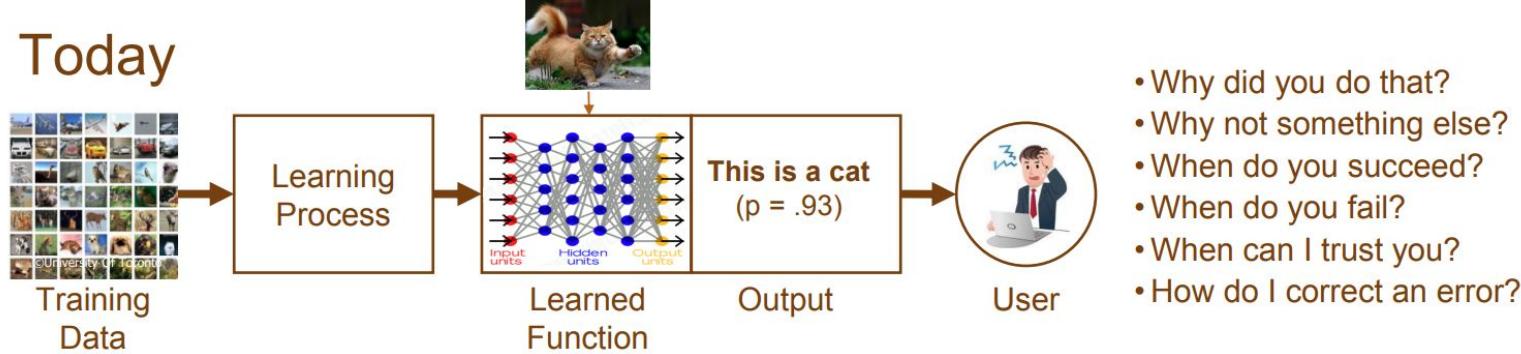


<https://github.com/Kitware/nrtk>  
<https://github.com/Kitware/nrtk-explorer>



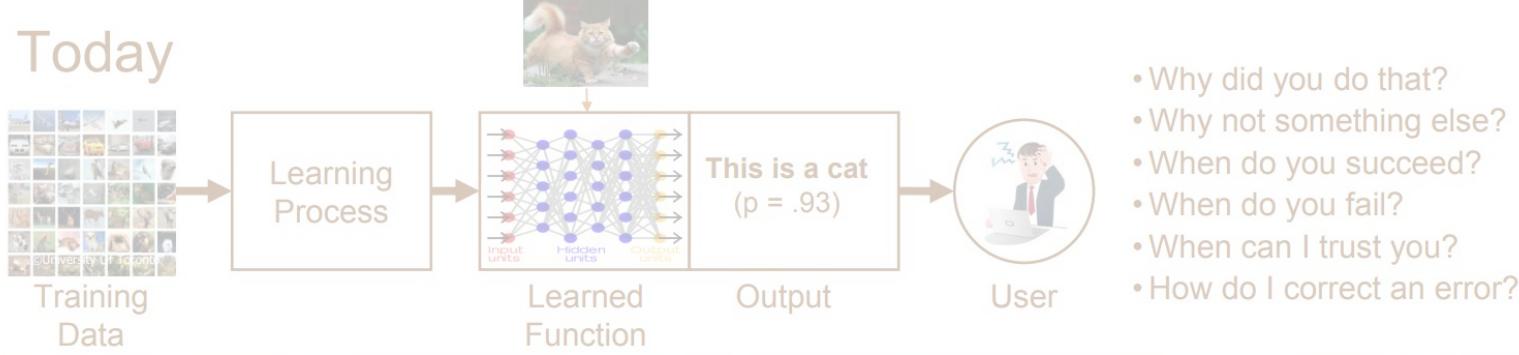
# Explainable AI (XAI) ?

Today

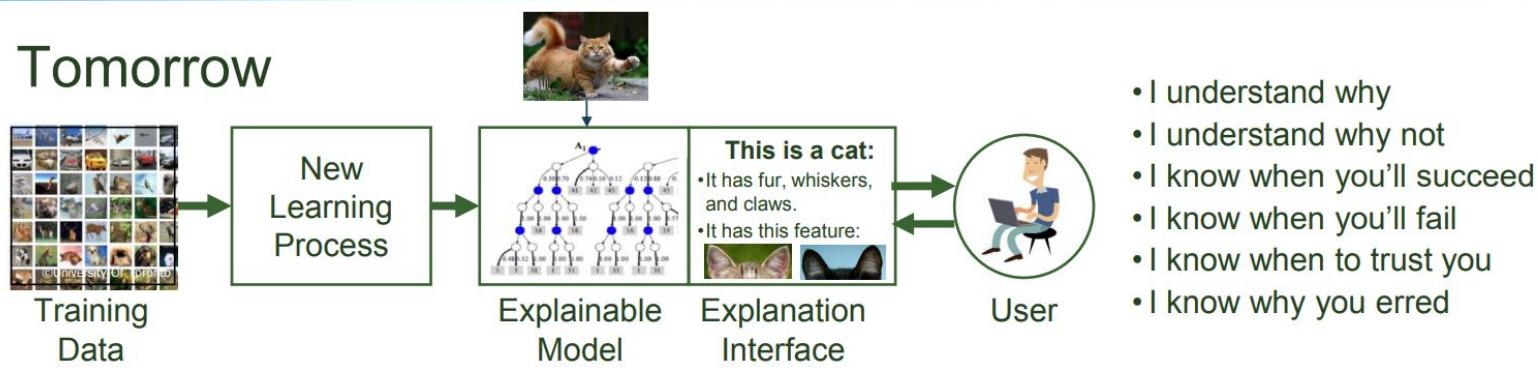


# Explainable AI (XAI) !

Today



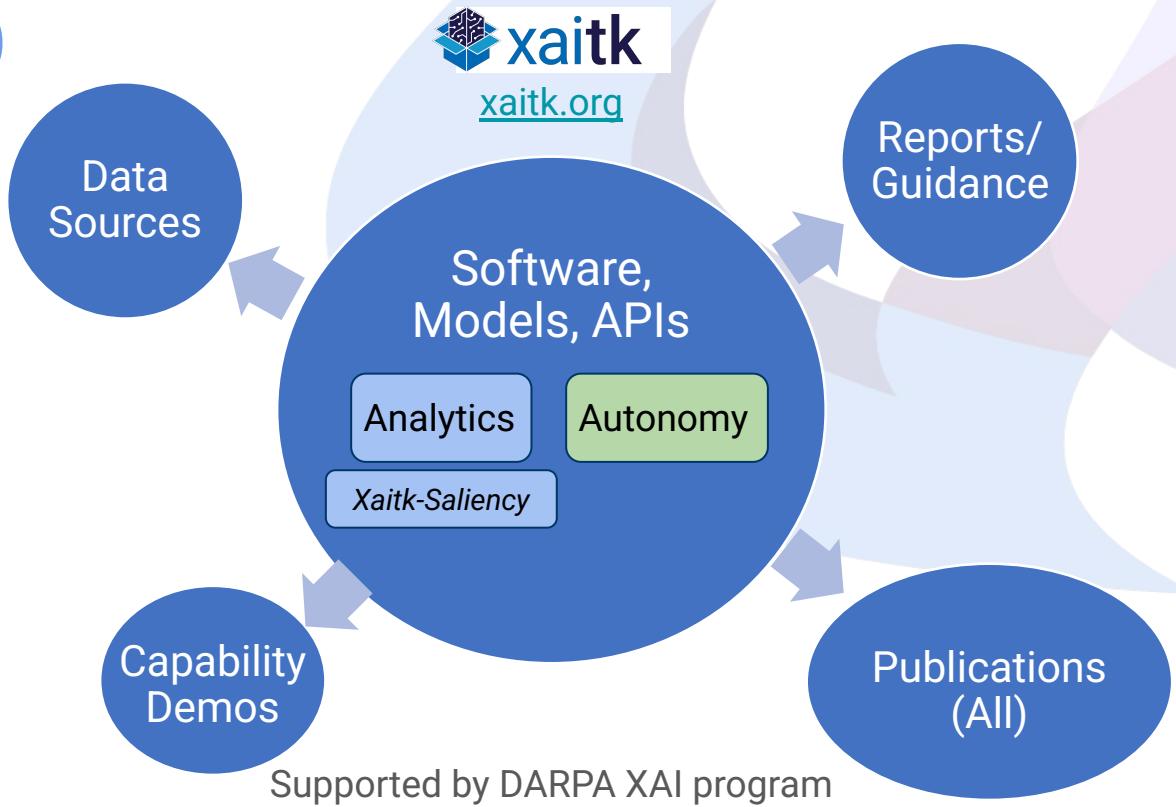
Tomorrow



# XAI Toolkit (XAITK)

## Highlights:

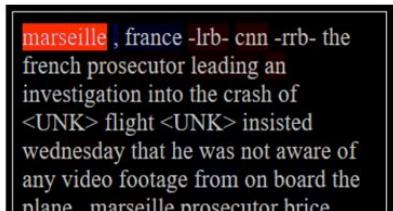
1. Searchable repository of XAI tools and resources
2. Easy to follow guide for what to use for a given task
3. Software framework built for analytics (*Xaitk-Saliency*)
4. Open-source, permissively licensed core with flexible licensing for plugins



Hu, B, Tunison, P, Vasu, B, Menon, N, Collins, R, Hoogs, A. XAITK: The explainable AI toolkit. *Applied AI Letters*. 2021; e40. doi:10.1002/ail2.40

# Saliency Maps as Explanations

Saliency maps are a form of *visual XAI*, overlaying the input with (typically) a heatmap to spatially indicate which areas of the input the AI found "important".



Saliency map for an algorithm on automatic text summarization ([Tuckey et al.](#))



Grad-CAM result for "Dog" ([Selvaraju et al.](#))



SBSM result showing where the image on the right is similar to the one on the left ([Dong et al.](#))



RISE result for importance of "Sheep" ([Petsiuk et al.](#))

# Explainable AI Toolkit (XAI Toolkit)

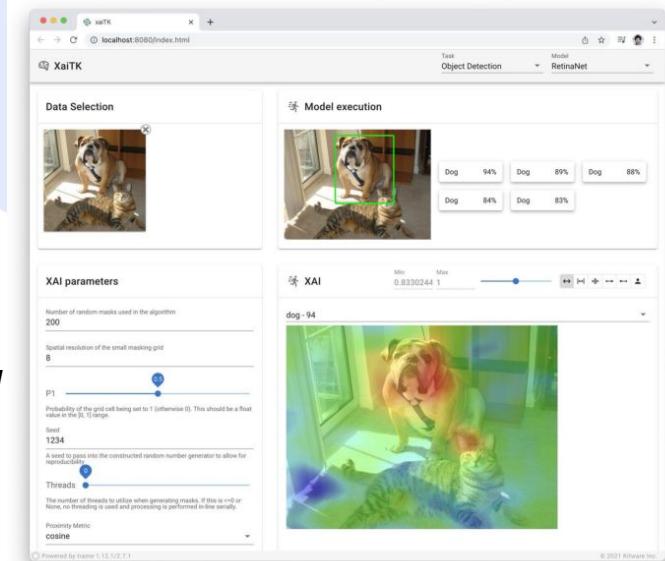
**XAI Toolkit (XAITK)** is a platform for visual saliency algorithms that enable human understanding of complex machine learning algorithms

## Background

- DARPA XAI created a suite of ML techniques that enabled human users to understand and appropriately trust the results of AI systems
- Collaborators included UC Berkeley, UCLA, Carnegie Mellon, UT Dallas, Texas A&M, Rutgers, Oregon State, SRI, Raytheon BBN, and IHMC
- XAITK combines the techniques and research performed throughout the DARPA XAI program into a unified and extensible package

## XAITK Use Cases

- Establish justified confidence in AI models, addressing *DoD Ethical AI Principles* of Traceability and Reliability
- Enable feature understanding and analysis for black-box AI models
- Provide analysis of model failure modes and edge cases



<https://www.darpa.mil/program/explainable-artificial-intelligence>  
<https://xaitk.org>  
<https://github.com/XAITK/xaitk-saliency>  
<https://github.com/XAITK/xaitk-saliency-web-demo>



## But where is trame?

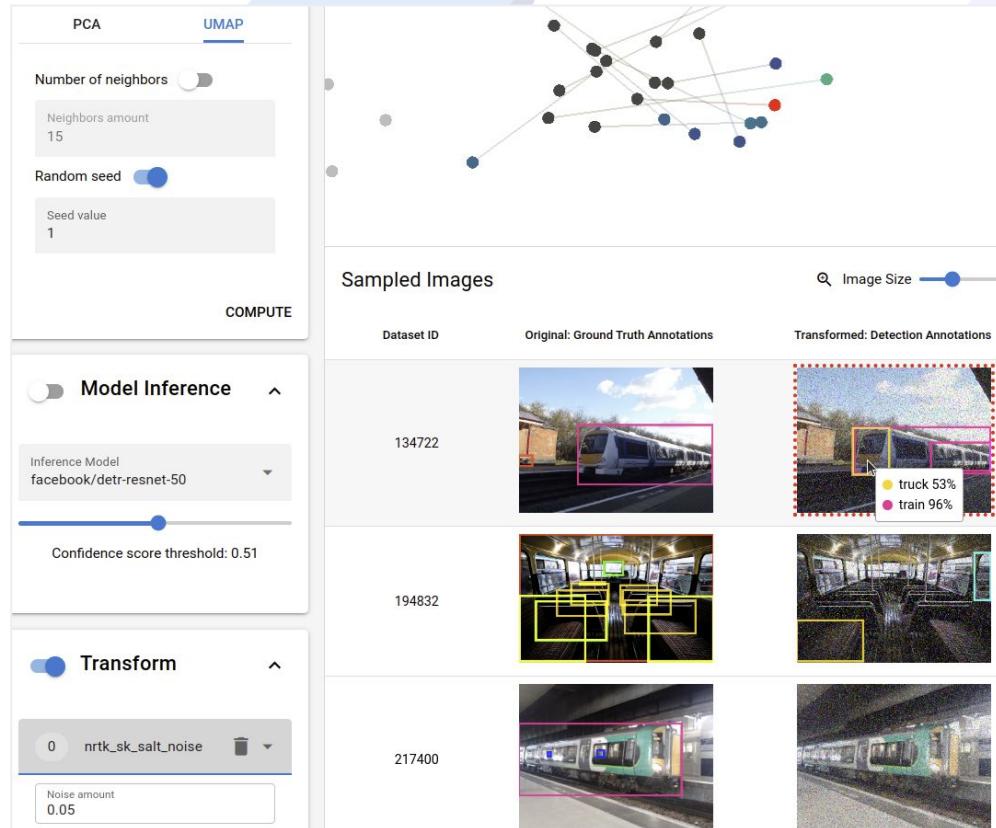
- By default a toolkit is never appealing unless you are a geek and you only work on a terminal.
- But what if you want to interactively try algorithms on your data?
- Trame is ideal for creating flexible GUI that offload the heavy lifting to other libraries.
- With trame we were able to create easy to install tools that can run locally (data privacy) or in cloud services.
- The XAITK demo application only took 1 week to create!
- The NRTK application is quite advanced due to the required generic approach toward perturbator and coco dataset import/export.

# NRTK Explorer App

<https://github.com/Kitware/nrtk-explorer>

## Dataset and Model Analysis Workflow

- Load models and datasets
- Group images in low-dimensional embedding space
- Filter by ground truth classifications
- Apply image perturbations
- Evaluate Object Detection and Classification inference results



<https://github.com/Kitware/nrtk>

<https://github.com/Kitware/nrtk-explorer>

# XAITK App

<https://github.com/XAITK/xaitk-saliency-web-demo>

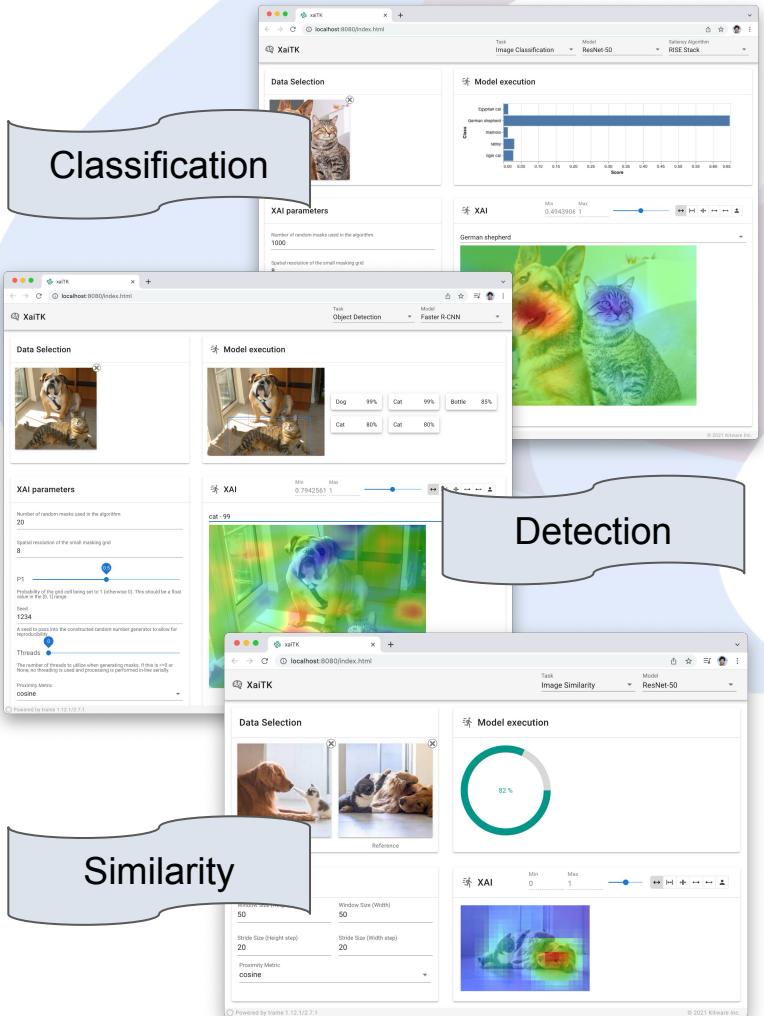
## Model Explanation Workflow

- Select task, AI model, XAI algo
- Upload image(s)
- Configure XAI algo
- Interactive XAI visualization



<https://github.com/XAITK/xaitk-saliency>

<https://github.com/xaitk/xaitk-saliency-web-demo>





This effort is lead by Brian Hu at Kitware.  
[brian.hu@kitware.com](mailto:brian.hu@kitware.com)

Disclaimer: This material is based upon effort sponsored by the U.S. Government under the Tradewind Project Agreement. The U.S. Government is authorized to reproduce and distribute reprints for Governmental purposes notwithstanding any copyright notation thereon. The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of the U.S. Government.

**THANK  
YOU  
FOR  
YOUR  
ATTENTION**