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SOL: Single middleware for optimized multi-architecture AI training and deployment

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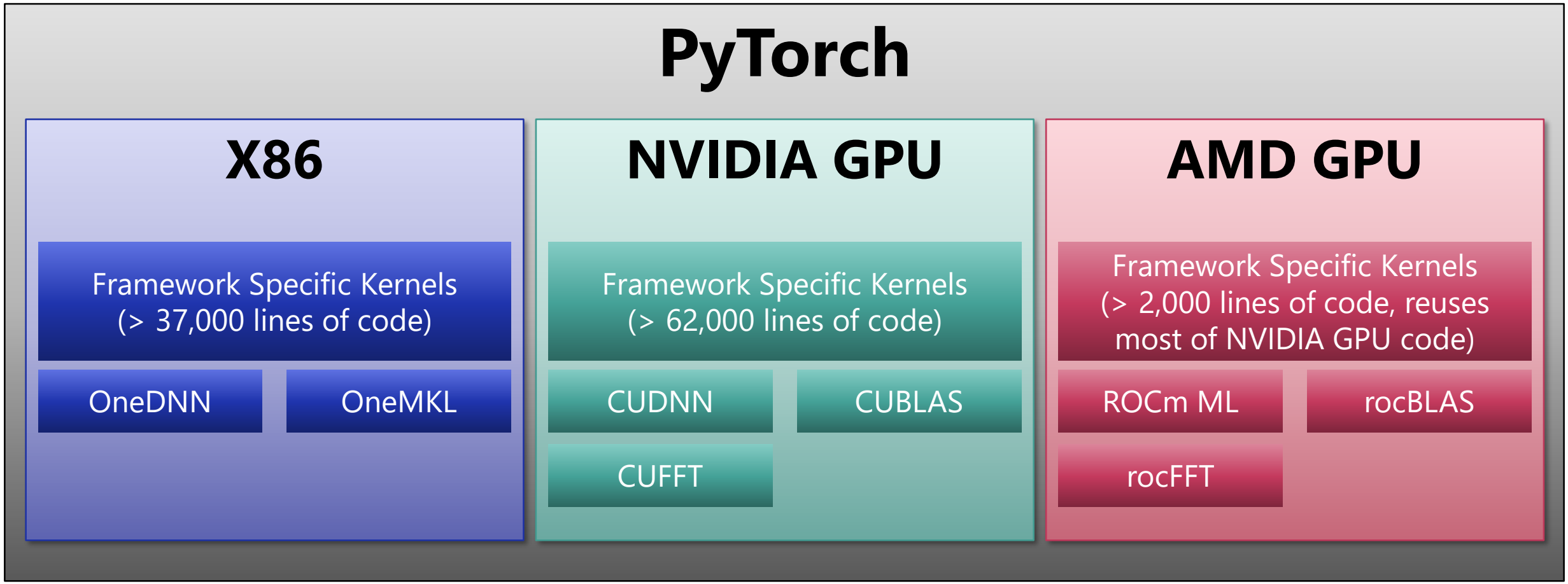
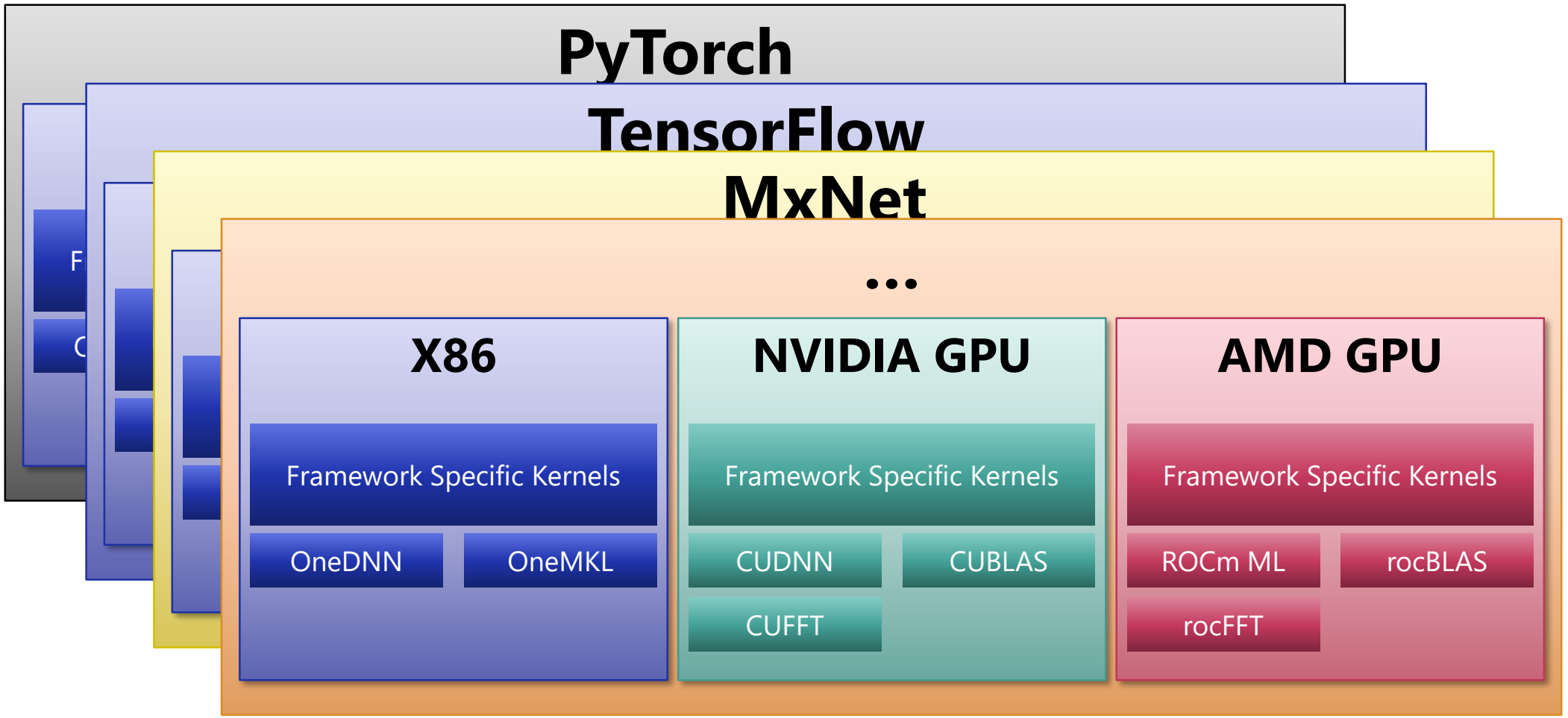
What are the challenges of hardware vendors when integrating their hardware in AI frameworks?

Hardware Support in AI Framework's today

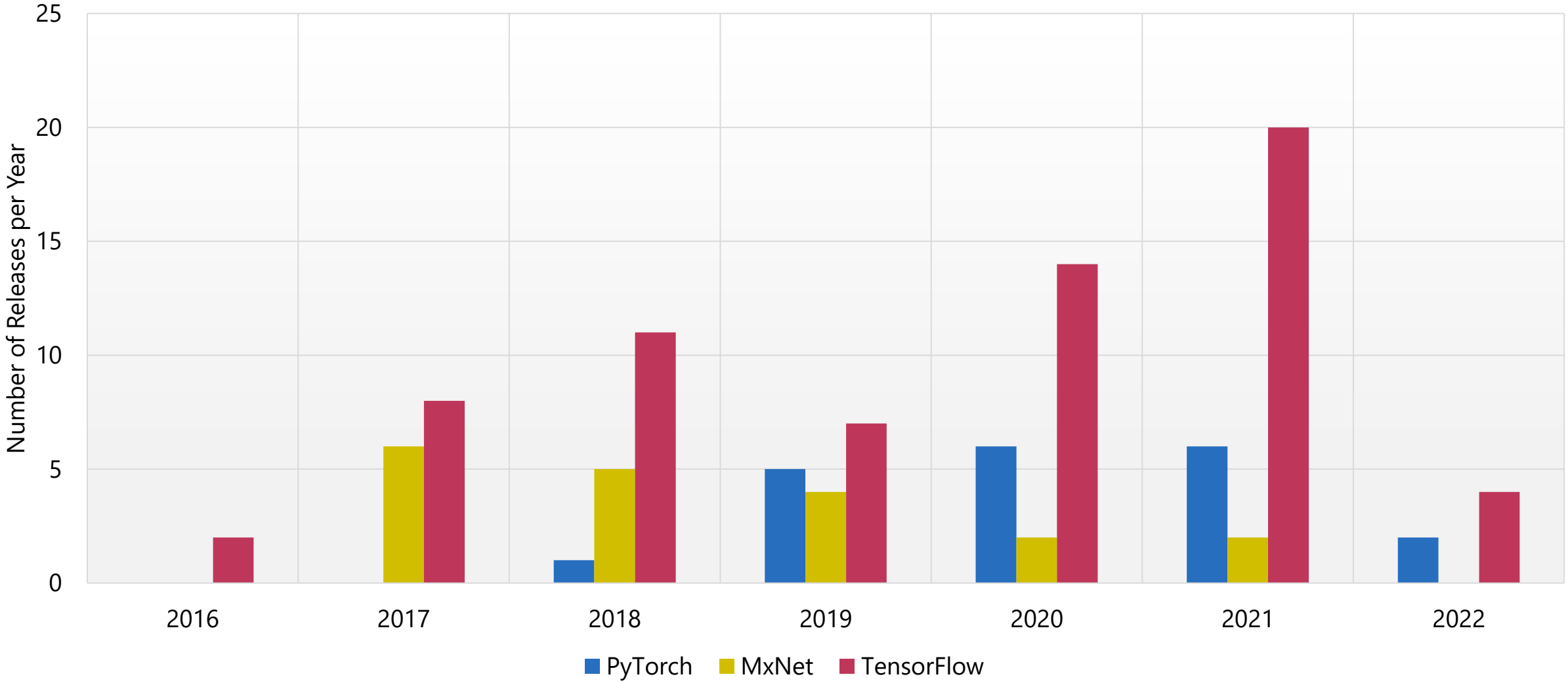


Hardware Support in AI Framework's today



Number of Releases (Major + Minor) per year

(numbers taken from PYPI)



Abstracting AI Frameworks

PyTorch | **TensorFlow** | **ONNX** | **DL4J**

SOL

DFP: Tensor Compiler

X86

Hardware Specific DFP Implementation

OneDNN | OneMKL

Σ 3,700 lines of code

NVIDIA GPU

Hardware Specific DFP Implementation

CUDNN | CUBLAS | CUFFT

Σ 2,100 lines of code

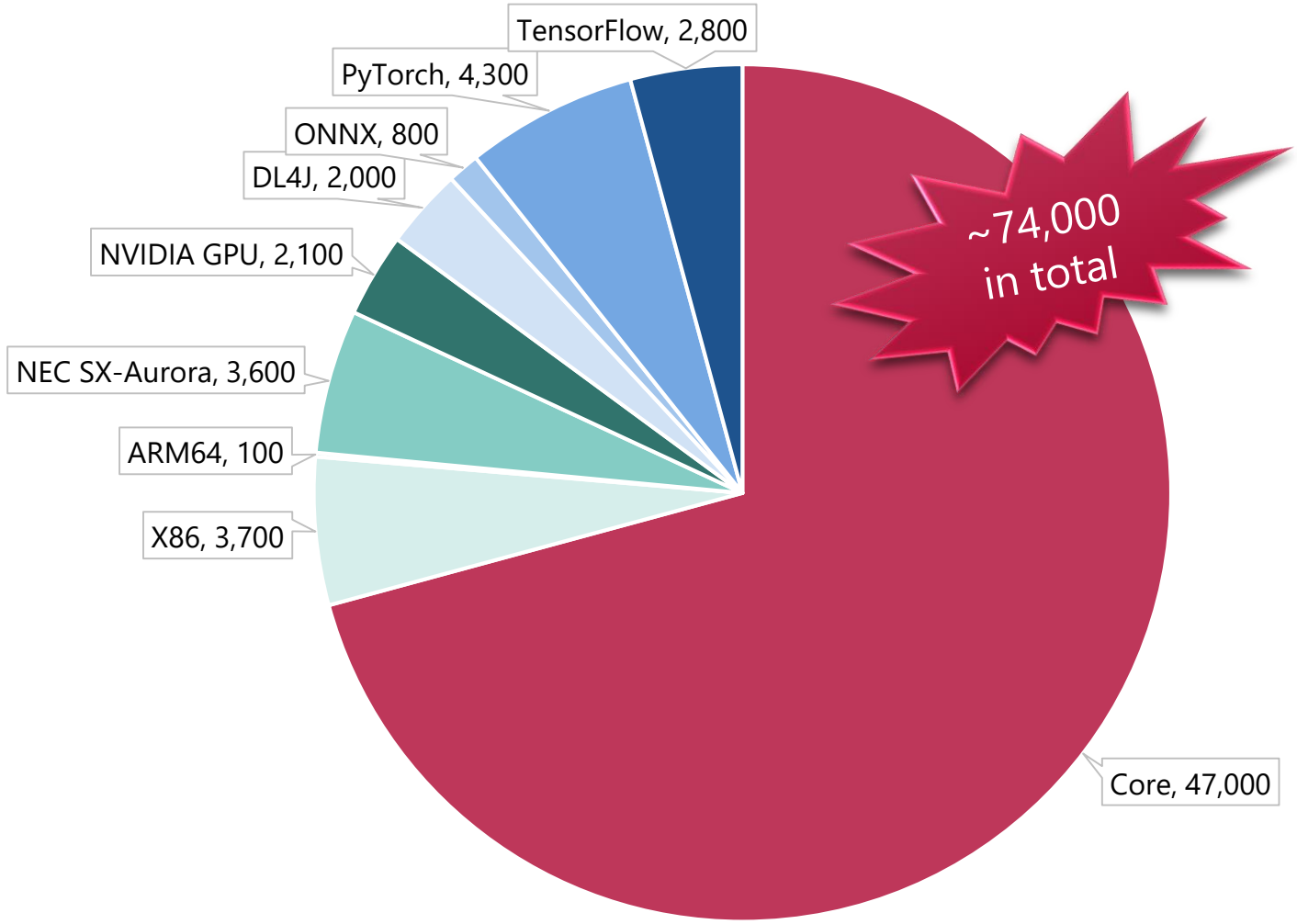
NEC SX-Aurora

Hardware Specific DFP Implementation

VEDNN | NLC

Σ 3,600 lines of code

SOL: Lines of Code per Component



OK that’s nice, but how to use SOL?

Optimizing neural network for Inference

```
# import packages
import torch
import torchvision



# load model and input data
model = torchvision.models.resnet50(pretrained=True)
input = torch.rand(1, 3, 224, 224)



# run inference mode
with torch.no_grad():
    output = model(input)
```

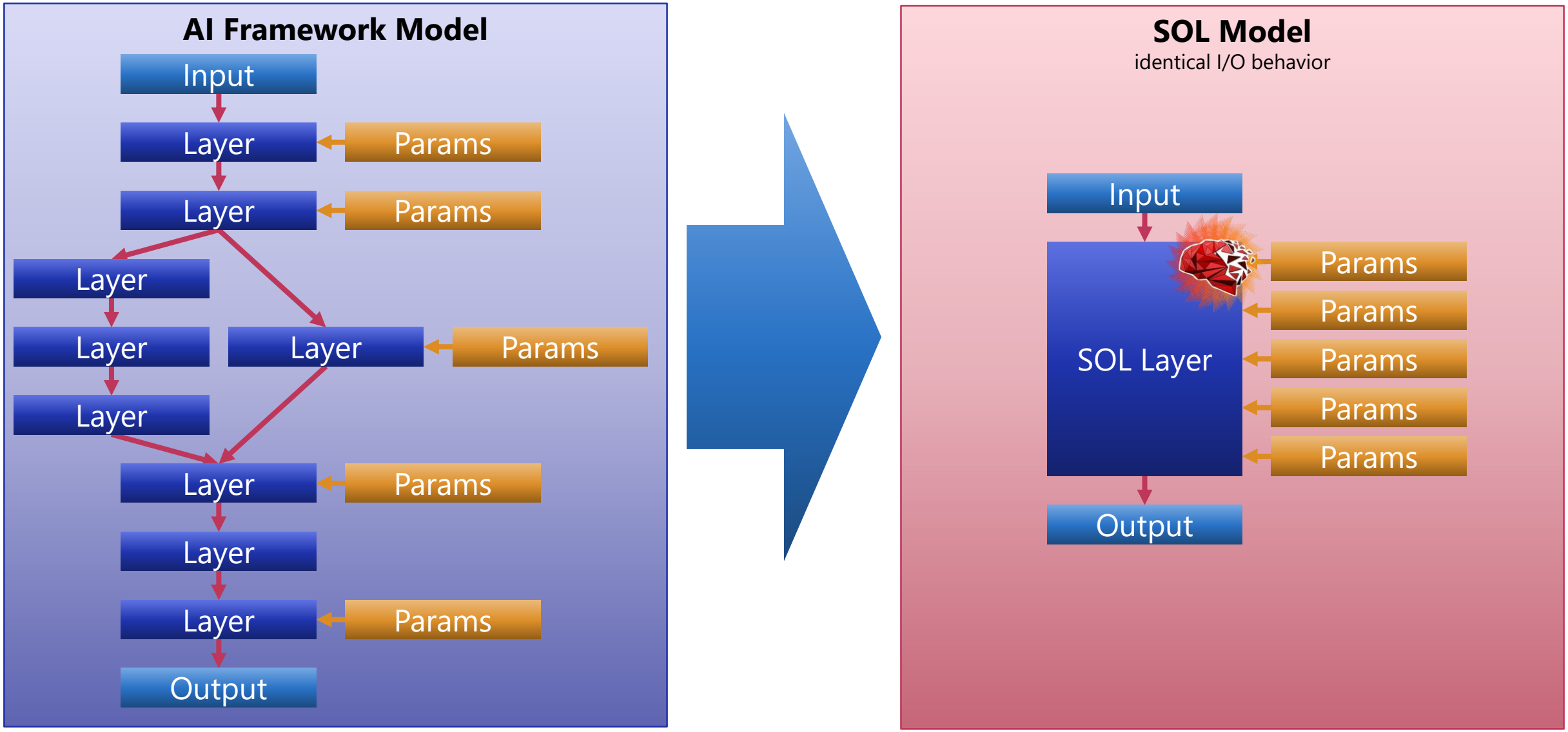
Optimizing neural network for Inference

```
# import packages
import torch
import torchvision
import sol

# load model and input data
model = torchvision.models.resnet50(pretrained=True)
input = torch.rand(1, 3, 224, 224)
model = sol.optimize(model, [input])

# run inference mode
with torch.no_grad():
    output = model(input)
```

sol.optimize(...)



And that’s all that is needed for adding device support to AI frameworks?

Graph vs Eager computations

```
input     = torch.rand(1, 3, 224, 224)
model     = sol.optimize(model, [input])
optimizer = torch.optim.sgd(model.parameters())

for input, target in dataset:
    output = model(input)
    loss = loss_func(output, target)
    loss.backward()
    optimizer.step()
```

Graph computations << executed + optimized by SOL
Eager computations << executed by AI framework

Eager Computation integration

- **VEDA-[PyTorch, TensorFlow]**
  - Separated from SOL since v0.5.0
  - https://github.com/SX-Aurora/veda-[pytorch, tensorflow]
  - Open Source License: BSD-3
  - Installation via: `pip3 install veda-[pytorch, tensorflow]~=[FRAMEWORK-VERSION]`
    (requires explicit linking against specific framework version)
  - Contains minimal subset of eager computations needed to run inference + training workloads in PyTorch and TensorFlow.

- **VEDA-PyTorch (1.10.2 and 1.11.0 supported)**
  - Required code: `import veda.pytorch`
  - Enables "VE" device and `tensor.ve(deviceIdx)`, `torch.ve.synchronize()`, etc.

- **VEDA-Tensorflow (2.6.3, 2.7.1 and 2.8.0 supported)**
  - Automatically loaded when importing TensorFlow
  - Just use: `with tf.device("/VE:0")`

Transparent Offloading

- Enables to execute workloads on accelerators in frameworks that don't allow to add new native devices, such as Numpy
  (more details: https://arxiv.org/abs/2003.10688)

```
import sol
import numpy as np
model = sol.optimize("my_onnx_model.onnx") # returns numpy a function
input = np.random.rand(1, 3, 224, 224)
sol.device.set("ve", 0)                    # sets VE#0 as executor
output = model(input)                      # computes on VE#0
```

Which other benefits does SOL have for me as a user?

AI Deployment: Runtime Engines

- **Runtime Engines**
  - ONNXruntime
  - LibTorch (PyTorch)
  - TensorFlow Lite
  - …
- **Pros**
  - Easy to use
  - Rapid deployment
- **Cons**
  - No compiler based optimizations
  - Large storage footprint (not including your AI model!)
    - LibTorch 1.11.0 with CUDA: **1.6GB**!
    - onnxruntime-gpu: 110MB

AI Deployment: AI Compilers

- **AI Compilers**
  - TVM (multi-vendor)
  - OpenVINO (all Intel Hardware)
  - TensorRT (NVIDIA)
  - Arhat (Fragata-AI)
  - …
- **Pros**
  - Optimized performance
  - Small storage footprint (only required functionality is shipped)
- **Cons**
  - usually vendor-locked (except TVM)
  - no guarantee that all functionality of your AI framework can be used
    (i.e. compilers usually use ONNX as input, but ONNX does not support complex dtypes, FFT, …)

AI Deployment: SOL

Pros

- Uses SOL optimizing compiler engine
- Supports ALL functionality of SOL (including FFT, complex dtypes, …)
- Multi-vendor
- Fully customizable runtime API
  (i.e. implement your own memory allocator)
- Allows static and shared linking

Cons

- still in experimental state
- not yet available for v0.5.0 release candidates, but will be released this summer!

Cross-Framework execution

- Enables to run foreign models, i.e., PyTorch model in TensorFlow!

```
import torch
from torchvision import models as tv
import sol
import numpy as np
import tensorflow as tf

with tf.device("VE:0"):
        input  = np.random.rand(1, 3, 224, 224)
        model  = sol.optimize(tv.resnet50(), [torch.from_numpy(input)], framework="keras")
        output = model.predict(input)
```

- **Available executors**
  - "pytorch" (torch.nn.Module)
  - "tensorflow" (tf.Module)
  - "keras" (tf.keras.model.Model)
  - "numpy" (Python function expecting inputs as np.ndarray)

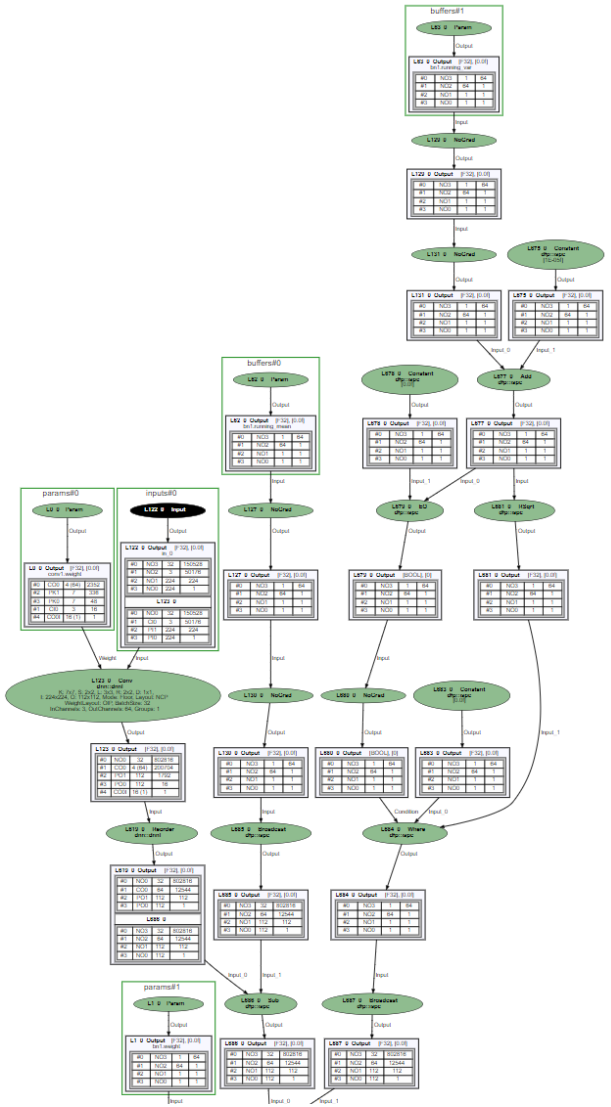
Additional Information

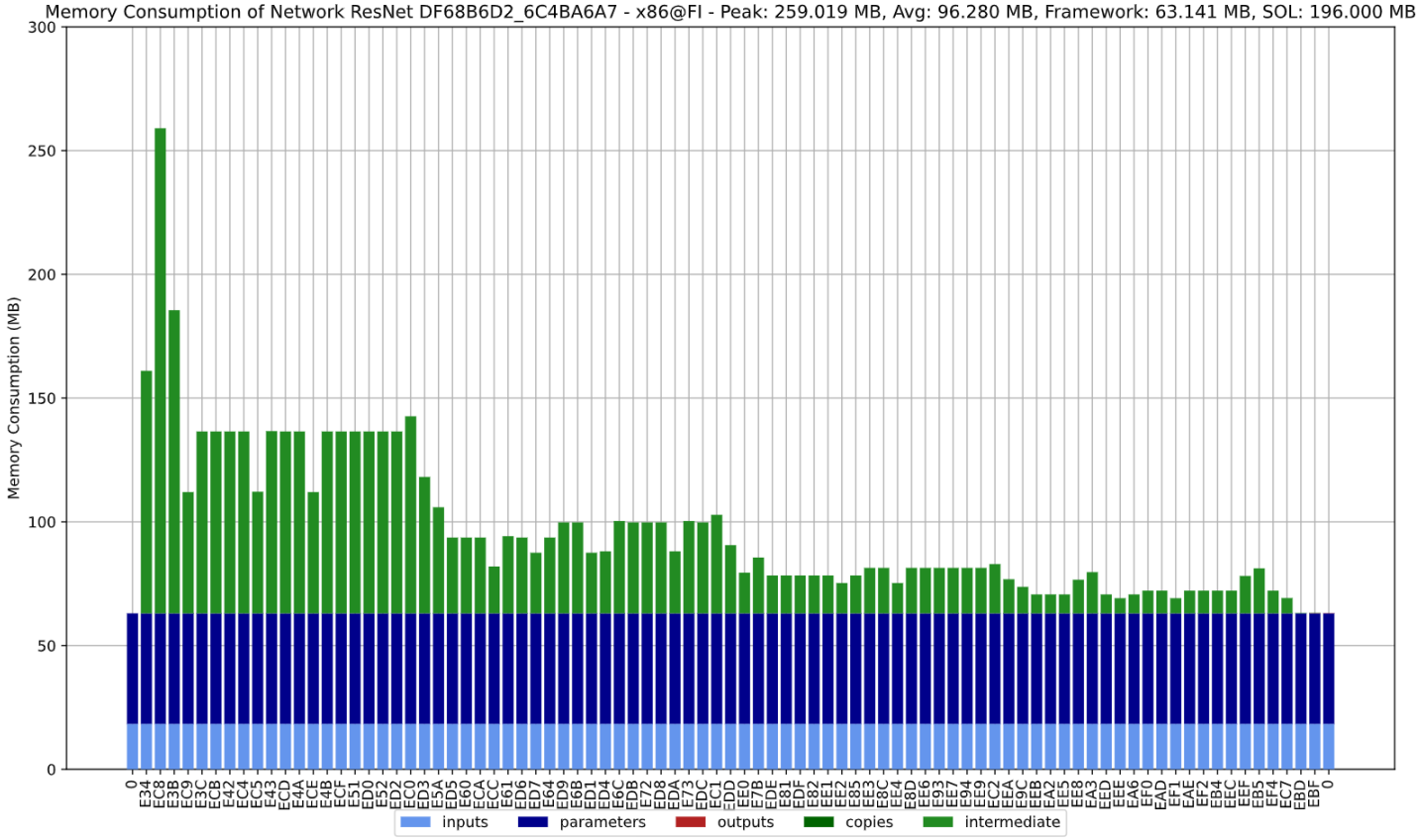
- Model Analysis (Input/Output Shapes, Model Parameters)
- Memory Consumption Estimation

```
Analyzing network ResNet (0xDF68B6D2)
Inputs:
    in_0: Tensor(dtype=[F32], shape=[32, 3, 224, 224])
Outputs:
    Tensor(dtype=[F32], shape=[32, 1000])
Model Parameters: 44.63MB
100% [##########################################################################]

Compiling network DF68B6D2_6C4BA6A7 for x86
100% [##########################################################################]
Estimated Peak Memory Consumption:
    Inference: ~260MB
    Training:  ~970MB
```

Additional Information: Computation Graph Visualization





That’s amazing! How can I get my hands on it?

How to get started?

- SOL is still in closed beta, BUT you can participate by requesting access through your NEC sales representative, Erich Focht or me
- Install SOL installer: `pip3 install --pre nec-sol`
- Use command-line installer

```
## NEC-SOL Package Manager v0.5.0rc1

Please choose an action:
> install/modify modules
  download modules
  list installed modules
  uninstall all modules
  options
  exit installer
```

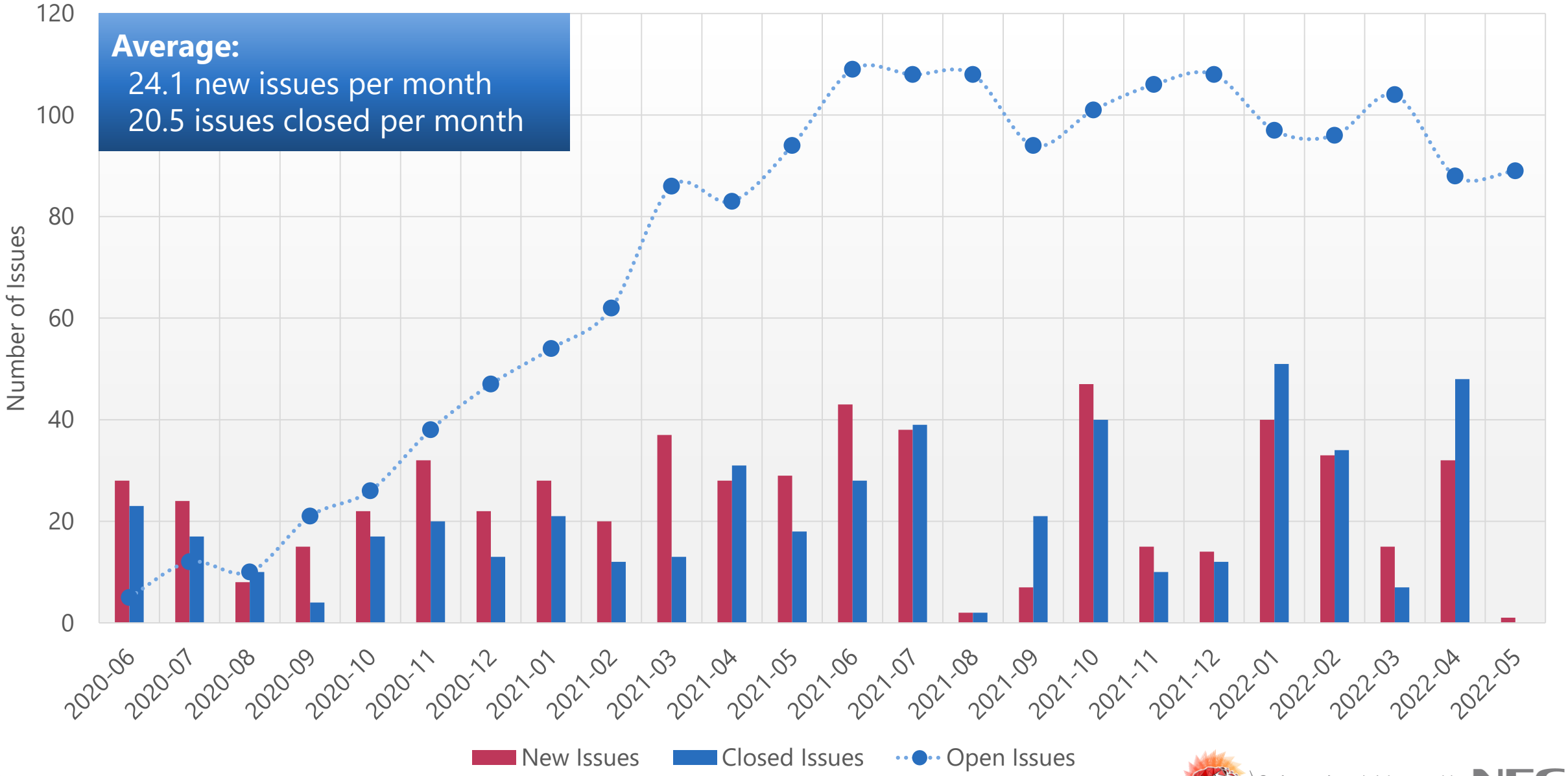
- More information in our documentation: https://sol.neclab.eu/docs

Upcoming SOL v0.5 Diadem release

- Since v0.5 we are using a "rolling releases"-model with release candidates every 2-4 months.

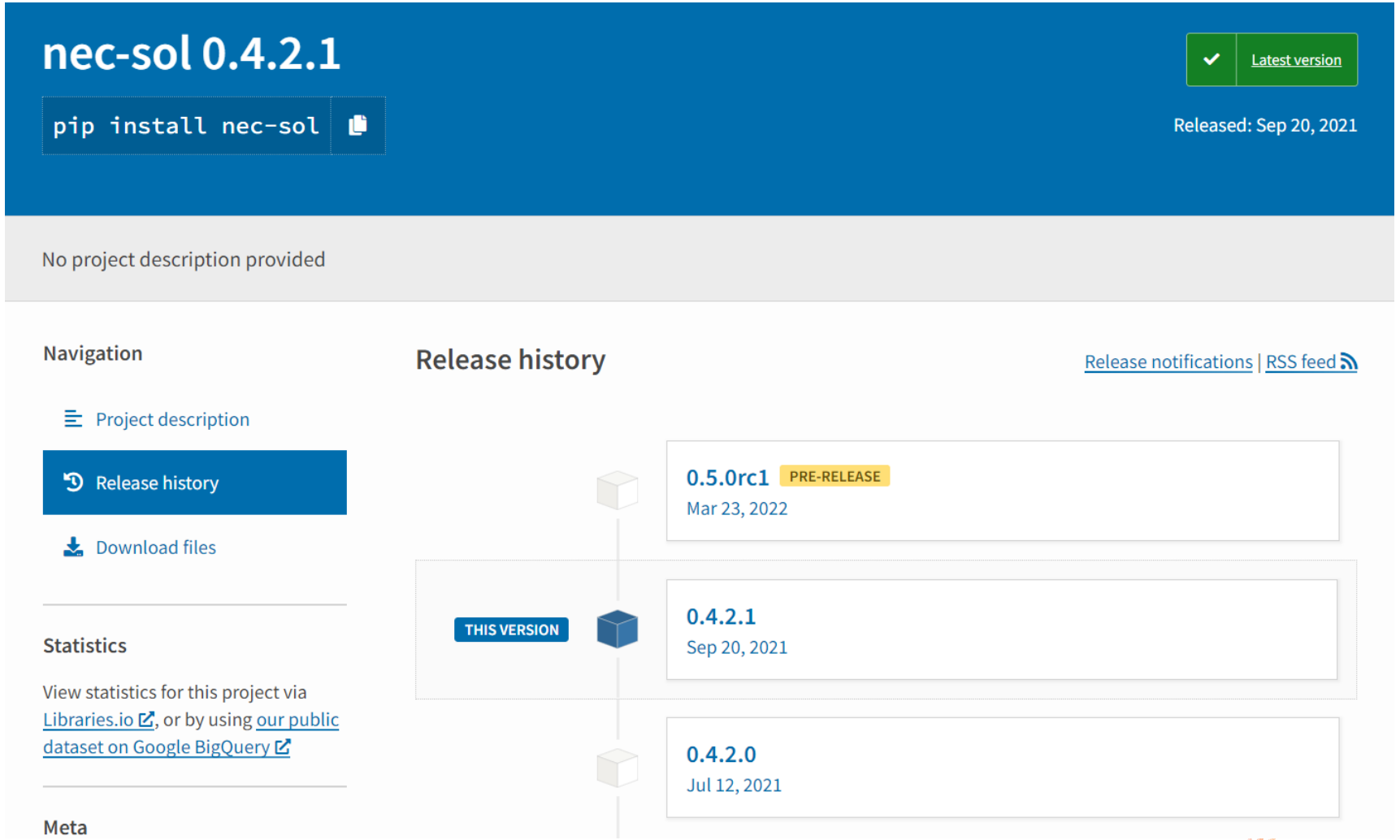
Feature	v0.5.0rc1 (March'22)	v0.5.0rc2 (May'22)	v0.5.0rc3 (Summer'22)
FFT	✓ X86 ✓ VE		
	#N/A		✓ NVIDIA
ONNX	#N/A	✓ upgraded to API-level 13 ✓ added more layers	
New Deployment System	#N/A		✓ static lib ✓ shared lib ✓ customizable API
Cross-Framework Execution	✓ PyTorch ✓ TensorFlow (Module + Keras)		
	#N/A	✓ Numpy	
New Dynamic Dimensions System	✓ see https://sol.neclab.eu/docs/v0.5.0/frameworks.html#variable-dimensions		

SOL Issue Tracker (https://gitlab.neclab.eu)



How to get notified about new versions?

- Subscribe to: https://pypi.org/rss/project/nec-sol/releases.xml



Thank you!

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We are looking for **new colleagues**, **visiting researchers** and **students**! Contact me if you are interested in working with us on HPC, Compiler, Scientific Computing, and other related topics!