MATLAB EXPO

Developing Service-Oriented Architecture and Implementing Using Adaptive AUTOSAR and DDS

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MathWorks®

Agenda

- Software-defined vehicles and new architectures (SOA)
- SOA Concepts
- MathWorks Solutions for SOA
    - Adaptive AUTOSAR
    - DDS/ROS
- Conclusions and key takeaways

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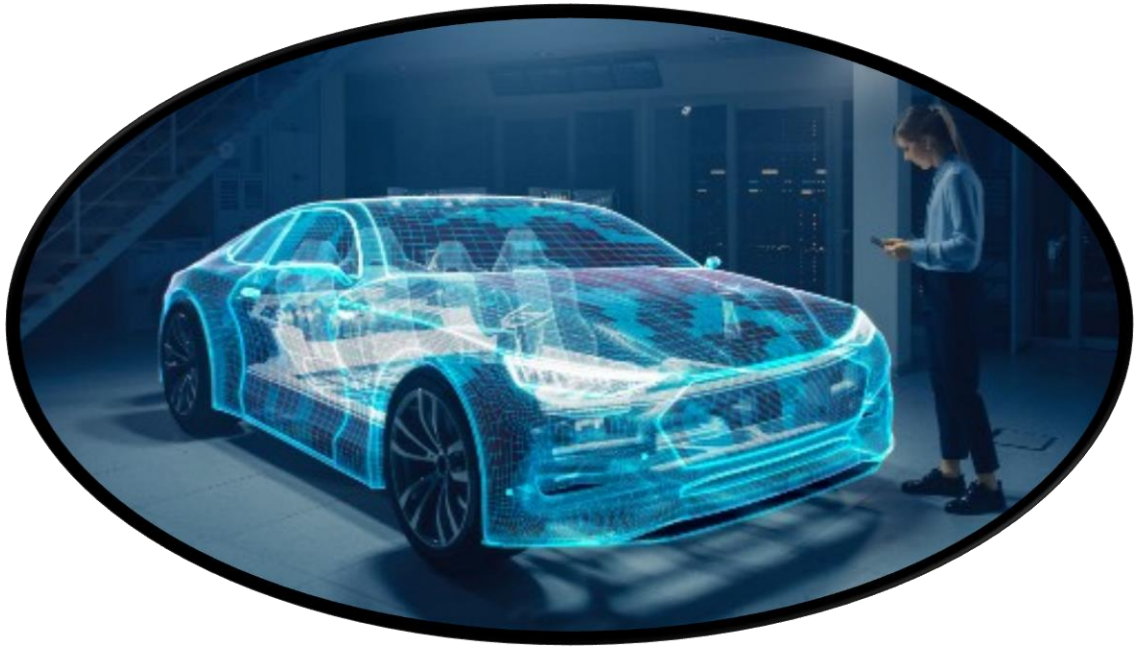
Software-defined vehicles



Brand-distinctive features and main value for the customer will come from Software

Software-defined vehicles

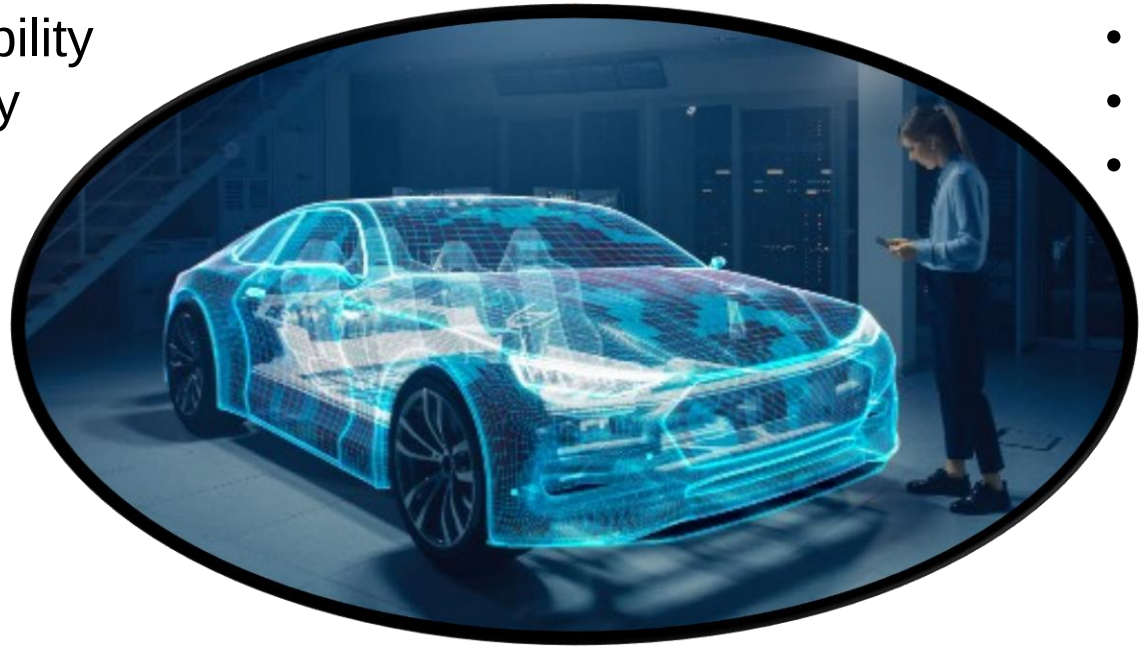
demand

Customer expectations

- Clean and Safe mobility
- Digital Life continuity

Technology & Innovation

- Electrification
- Autonomy
- Connectivity



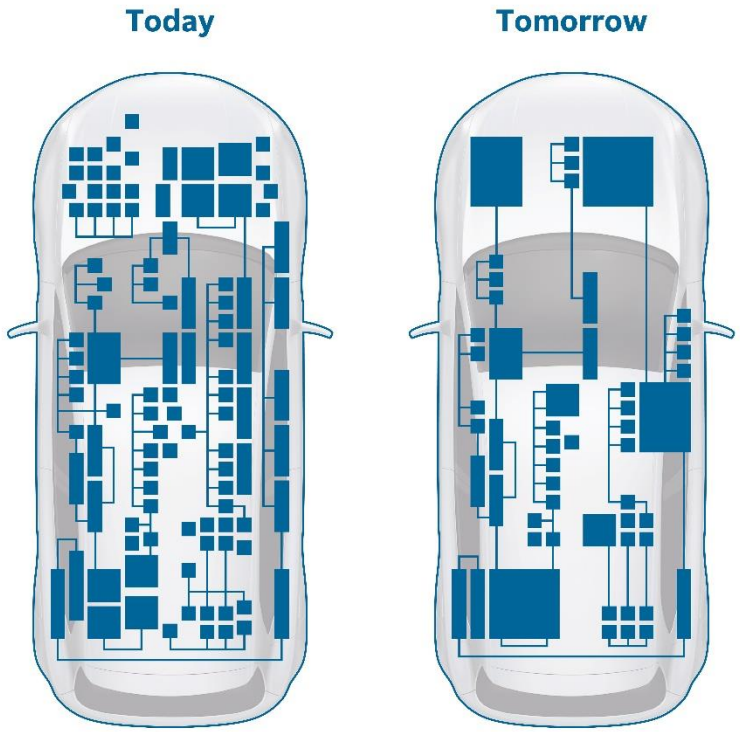
monetize

invest

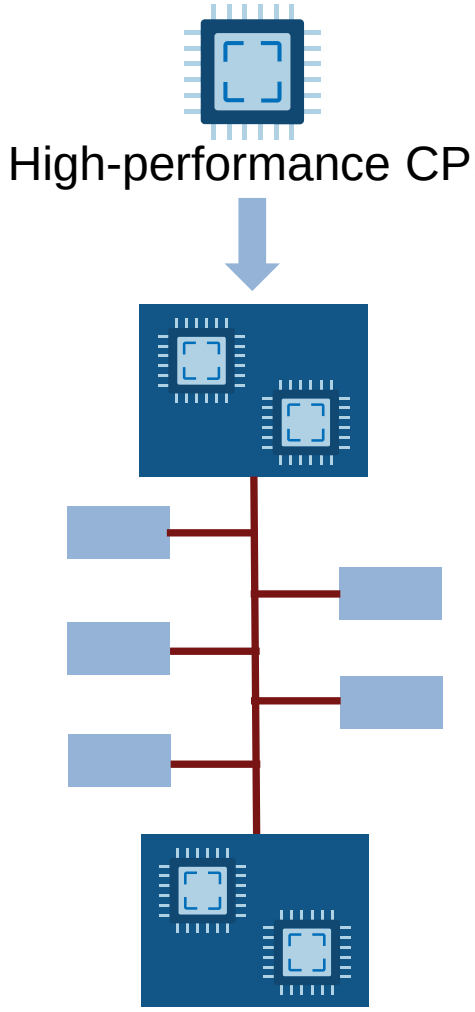
Business opportunity

- App stores, SW features on demand
- SW services subscription plans

Centralization of computing and SOA



Consolidation and centralization of computing

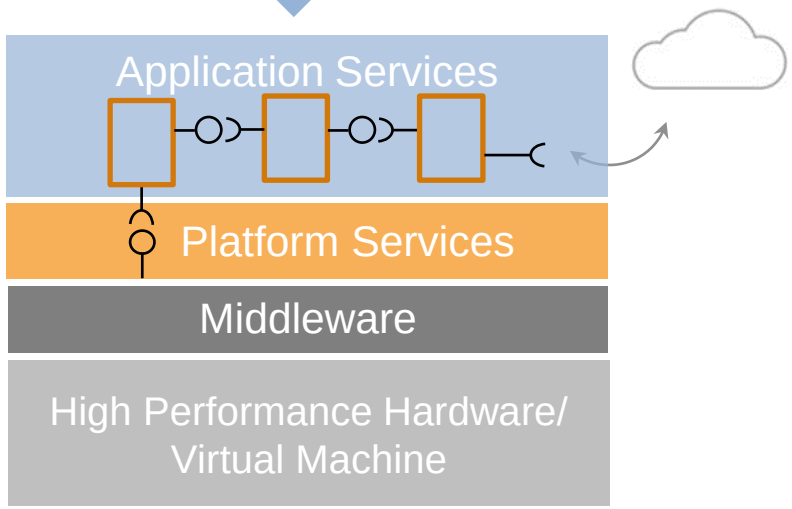


High-performance CPU/GPU

New E/E zonal architectures

SW updates

- Frequent
- Selective
- Over-the-air



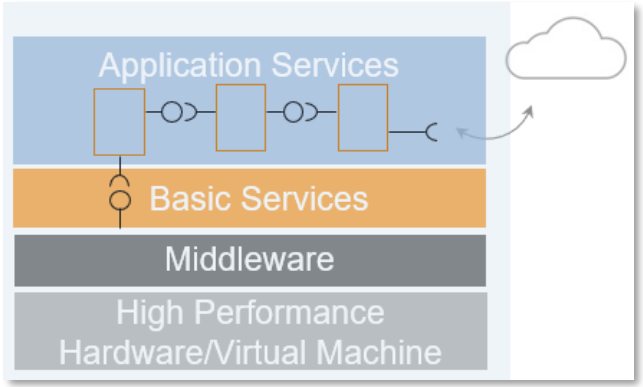
Higher HW abstraction:
Service-oriented architectures

Agenda

- Software-defined vehicles and new architectures (SOA)
- SOA Concepts
- MathWorks Solutions for SOA
  - Adaptive AUTOSAR
  - DDS/ROS
- Conclusions and key takeaways

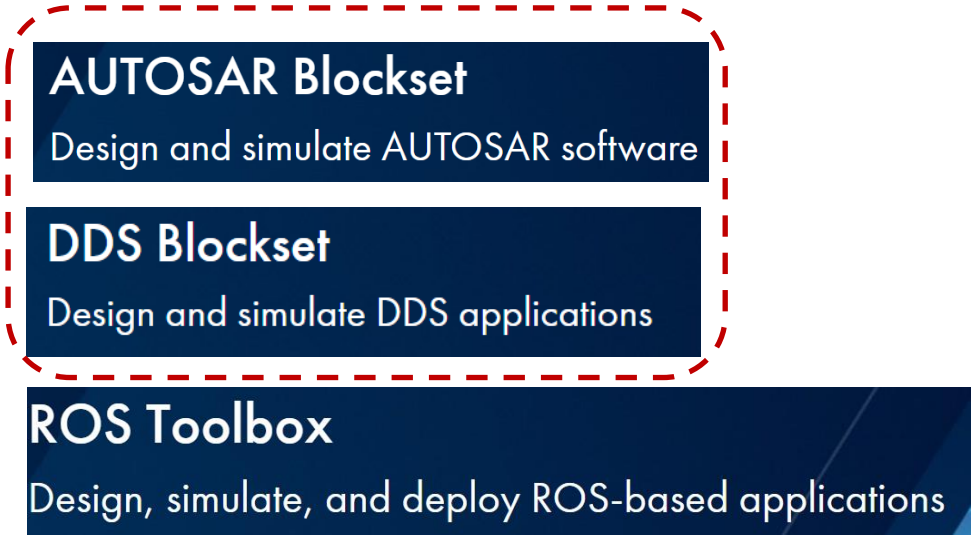
SOA – What's it all about?

- With SOA, applications are standalone processes that provide and/or require services distributed across the vehicle computing platform and the cloud

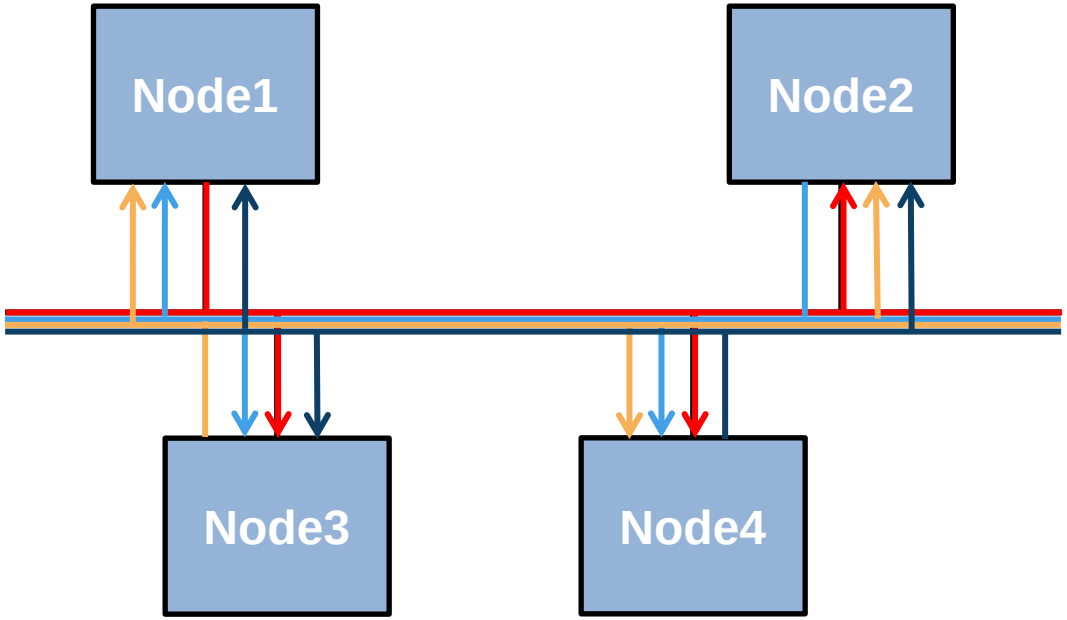


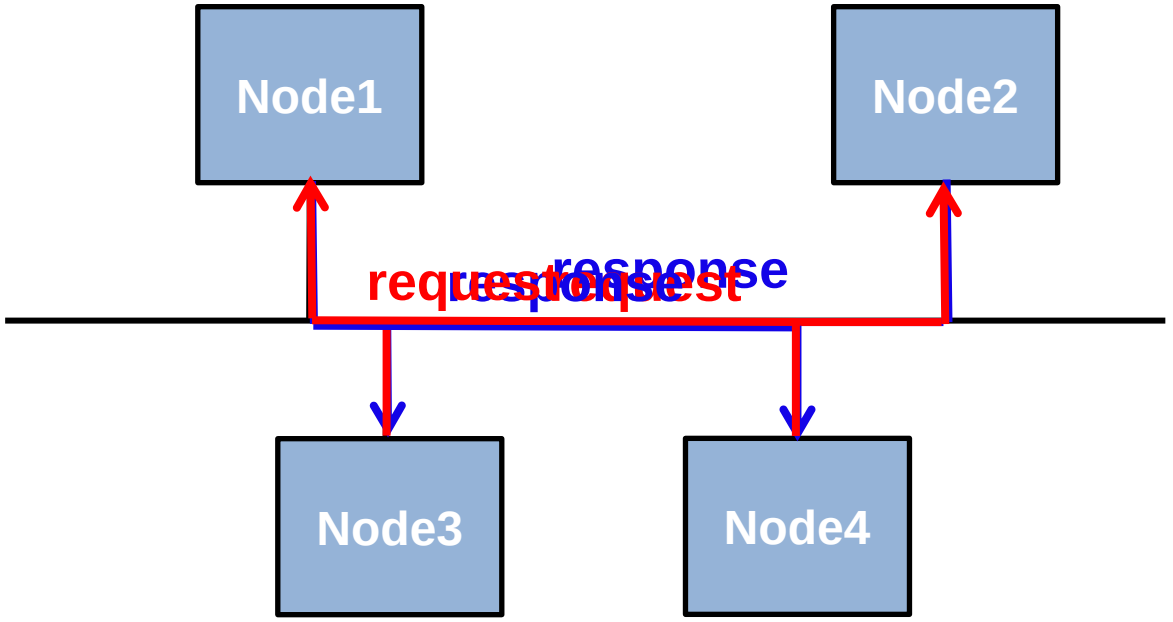
- SOA provides flexibility to add, remove, or update applications without impacting the entire, typically large, software system

- SOA is used by multiple industrial standards:
  - AUTOSAR Adaptive Platform
  - DDS (Data Distribution Services)
  - ROS (Robot Operating System)



SOC (Service Oriented Communication)





signal-oriented communication

- send data independent of needs
- high bus load
- not efficient

service-oriented communication

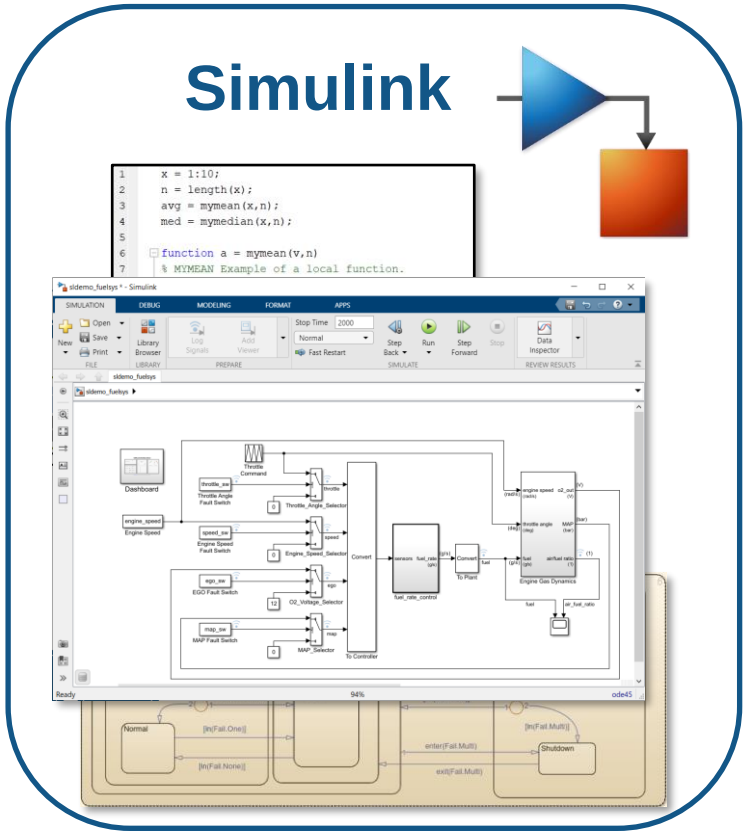
- send data dependent of needs
- low bus load
- more efficient

Key Challenges

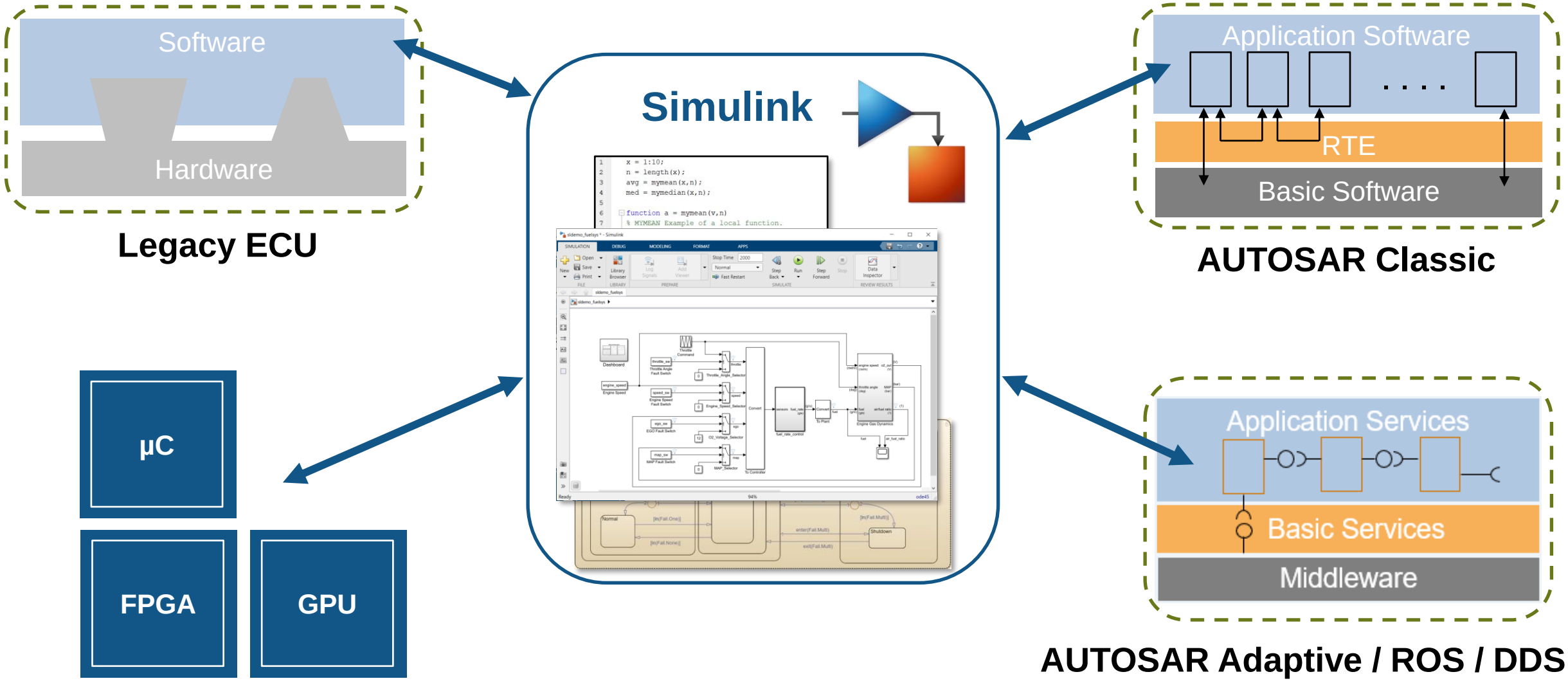
- Service-oriented architectures require a **change of mindset**
  - Shift from time-driven to event-driven execution
- **Centralize, re-architect** existing applications and partition in processes and services
  - e.g. Centralize energy management and path planning
- **Reuse of existing expertise**, workflows and software assets (don’t start from scratch)
  - Migrate software components from AUTOSAR Classic to AUTOSAR Adaptive

MathWorks is collaborating with OEMs and Suppliers to address these challenges

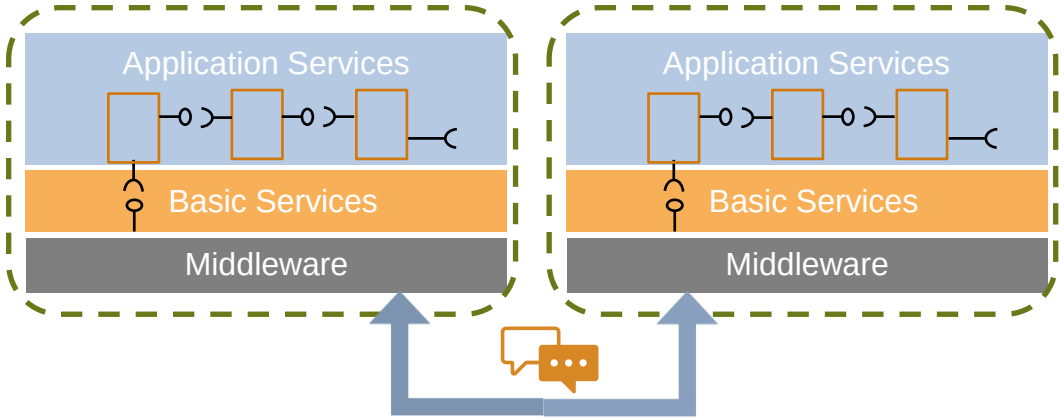
Simulink: Deploy software to different targets and standards



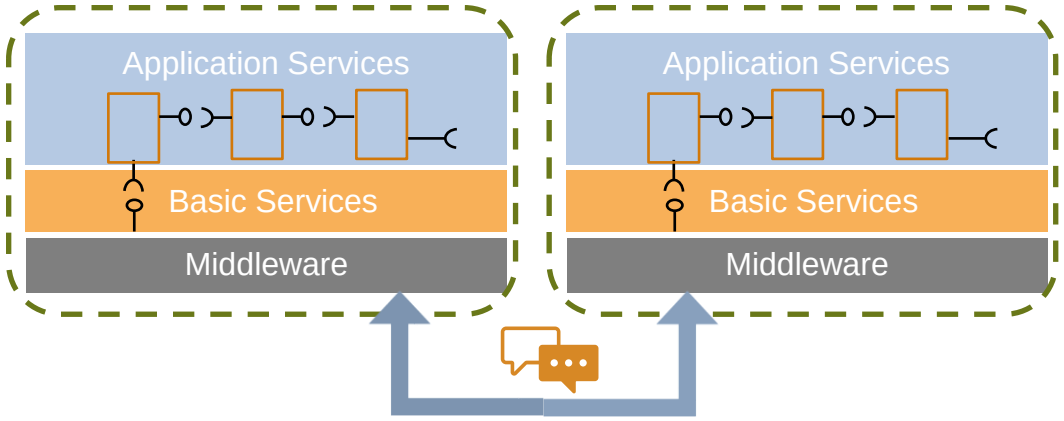
Simulink: Deploy software to different targets and standards

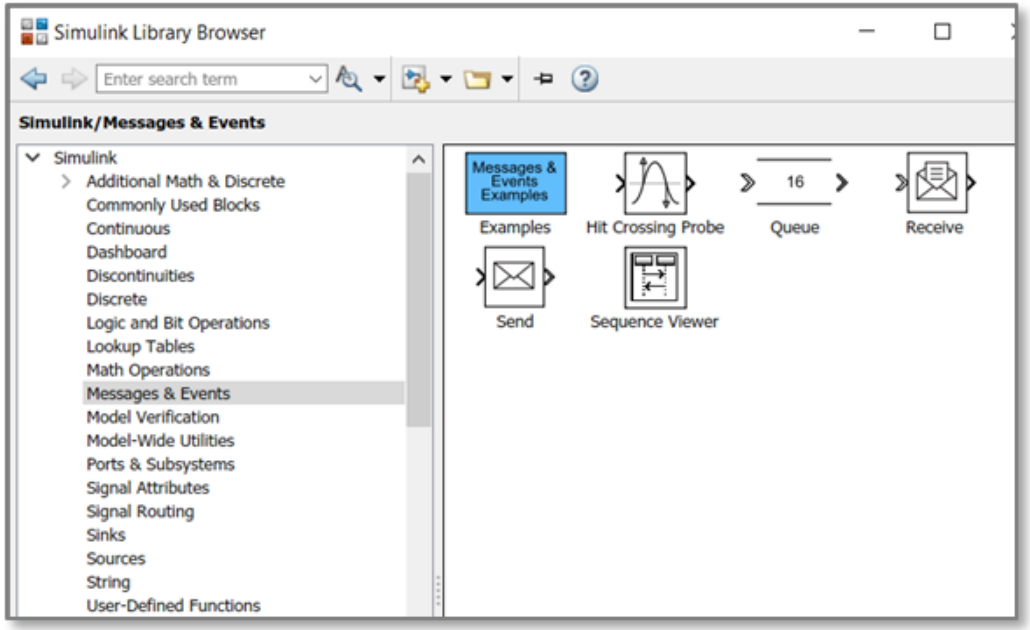


Simulink Messages for Service-oriented communication



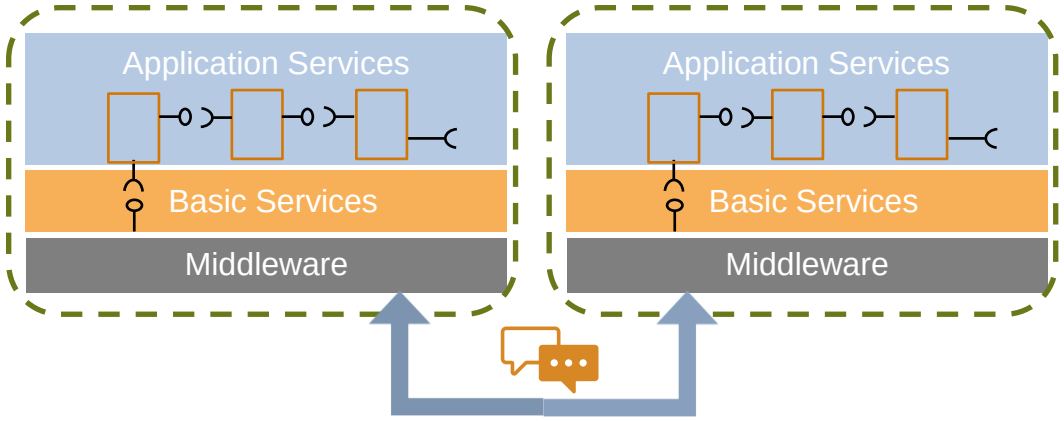
Simulink Messages for Service-oriented communication

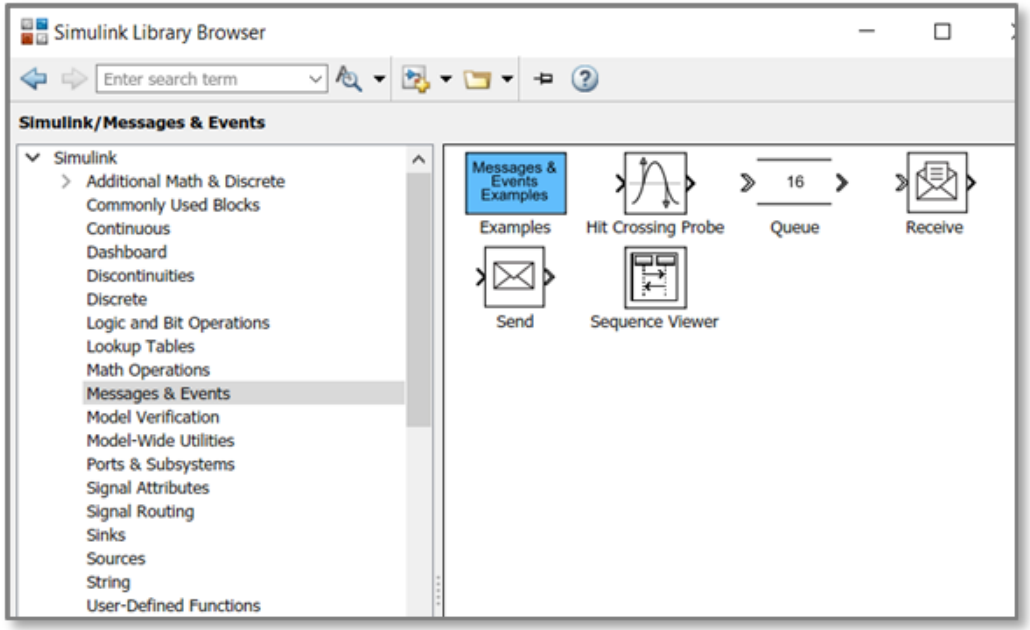


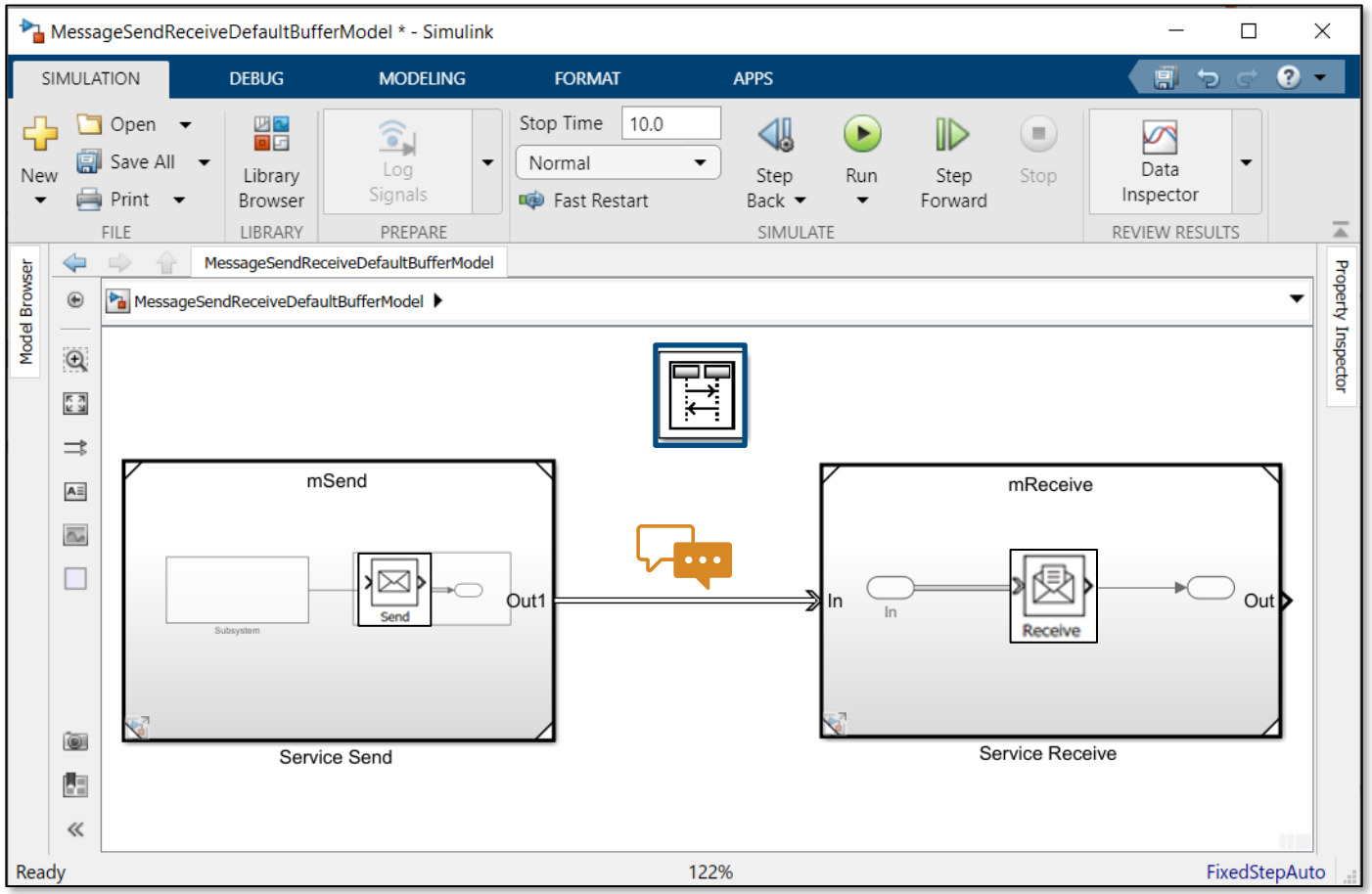


You can model service-oriented communication using messages (Send/Receive).

Simulink Messages for Service-oriented communication







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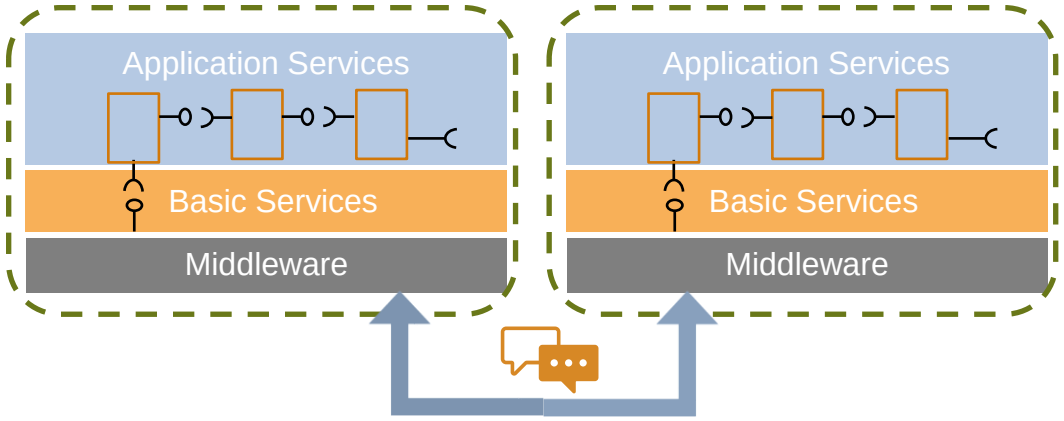
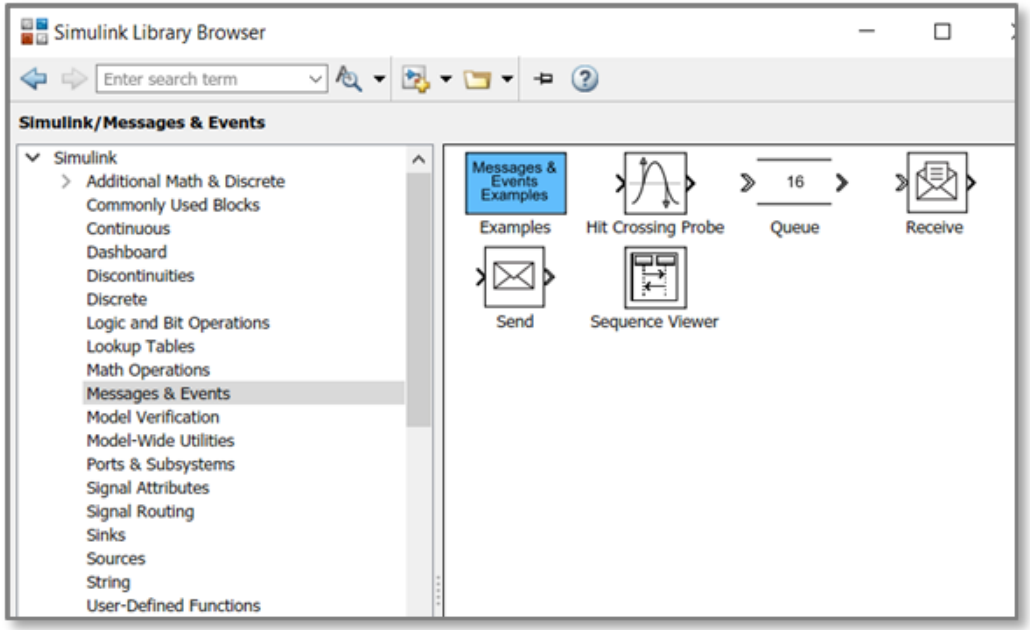
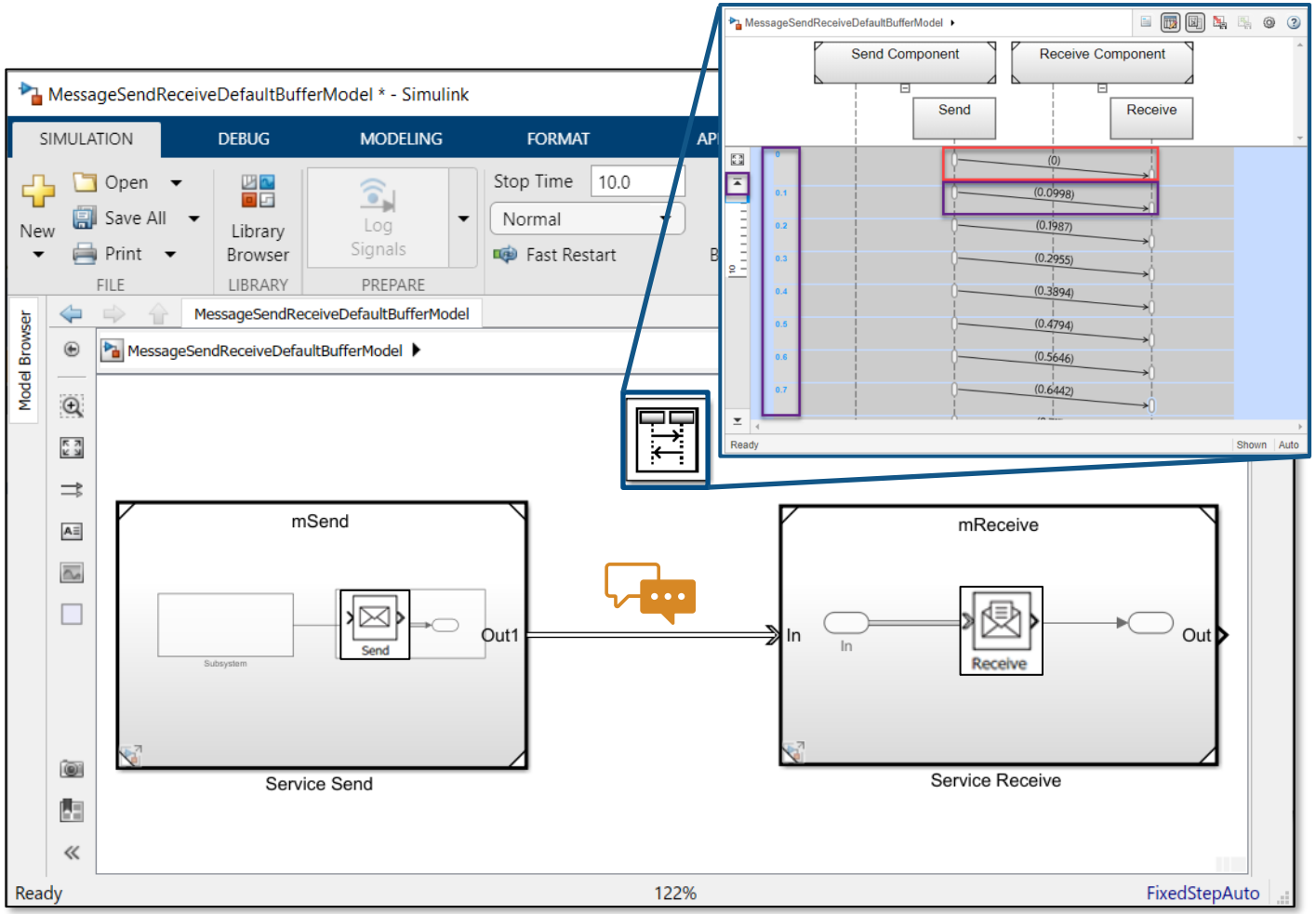
Simulink Messages for Service-oriented communication

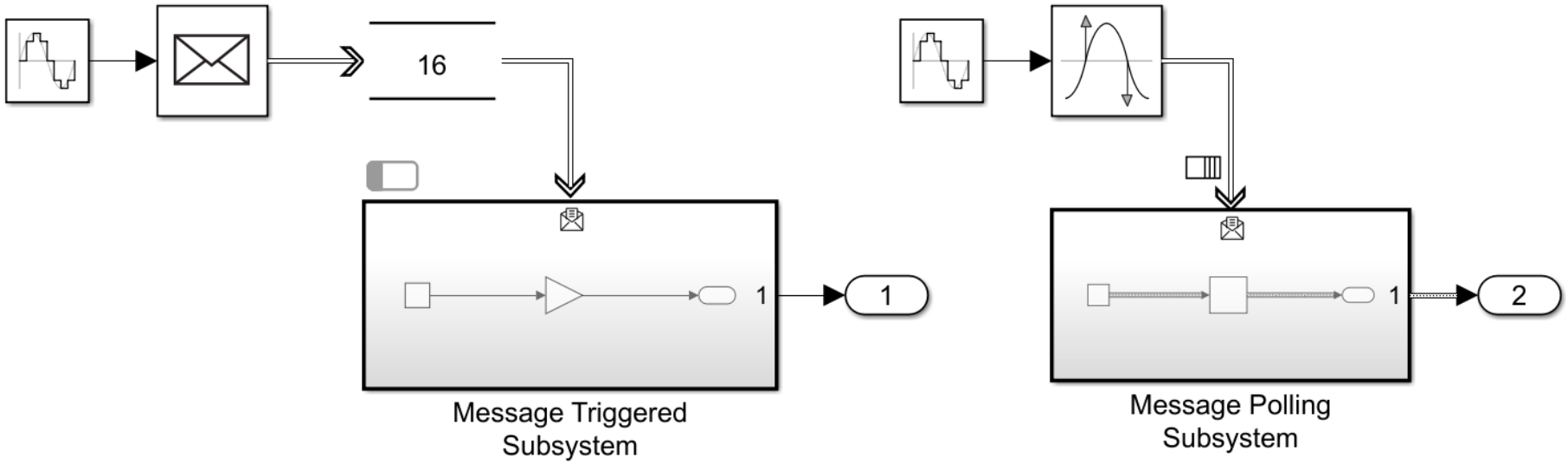






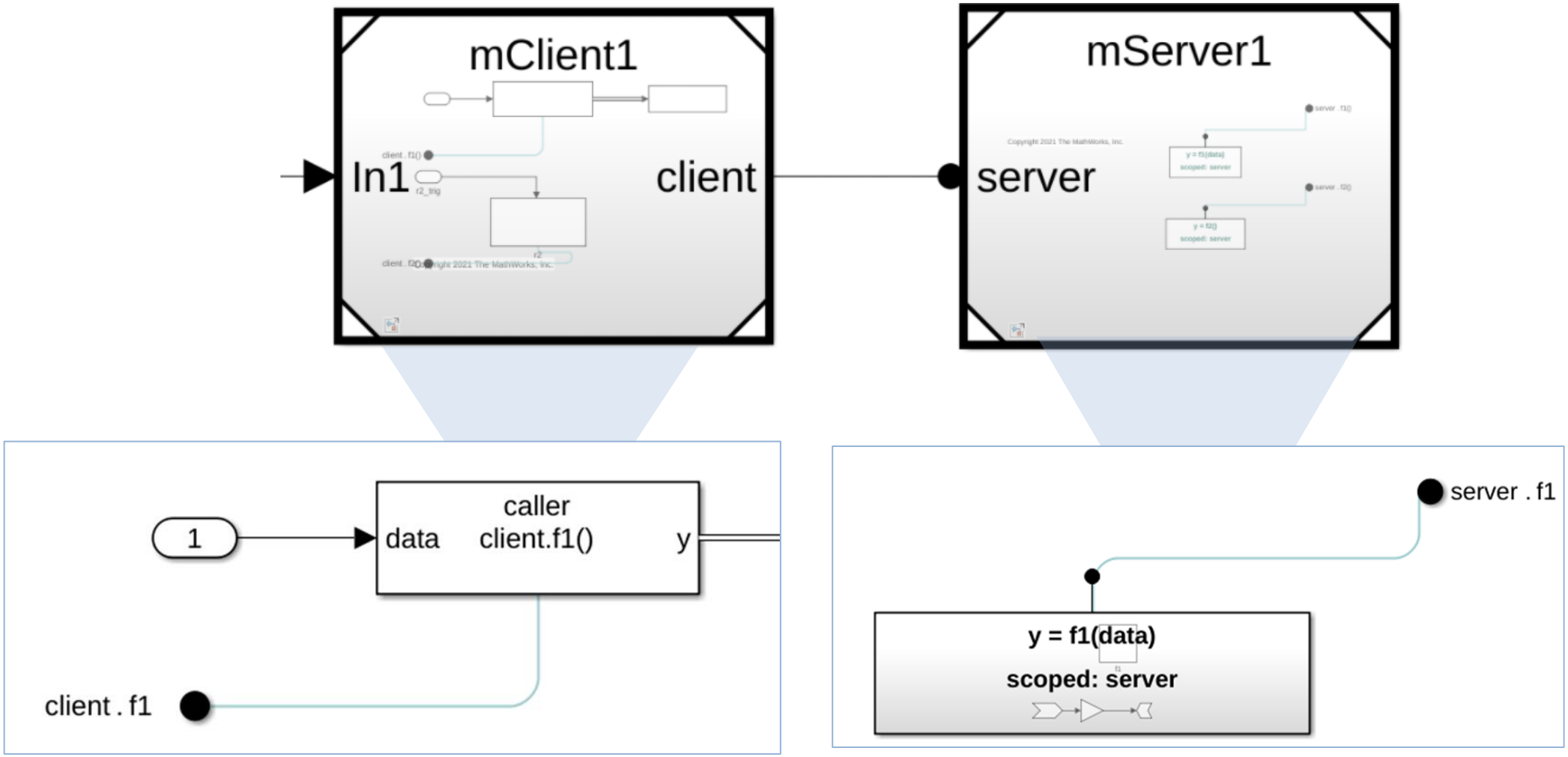
You can model service-oriented communication using messages (Send/Receive).

Message Triggered/Polling Subsystem for SOA



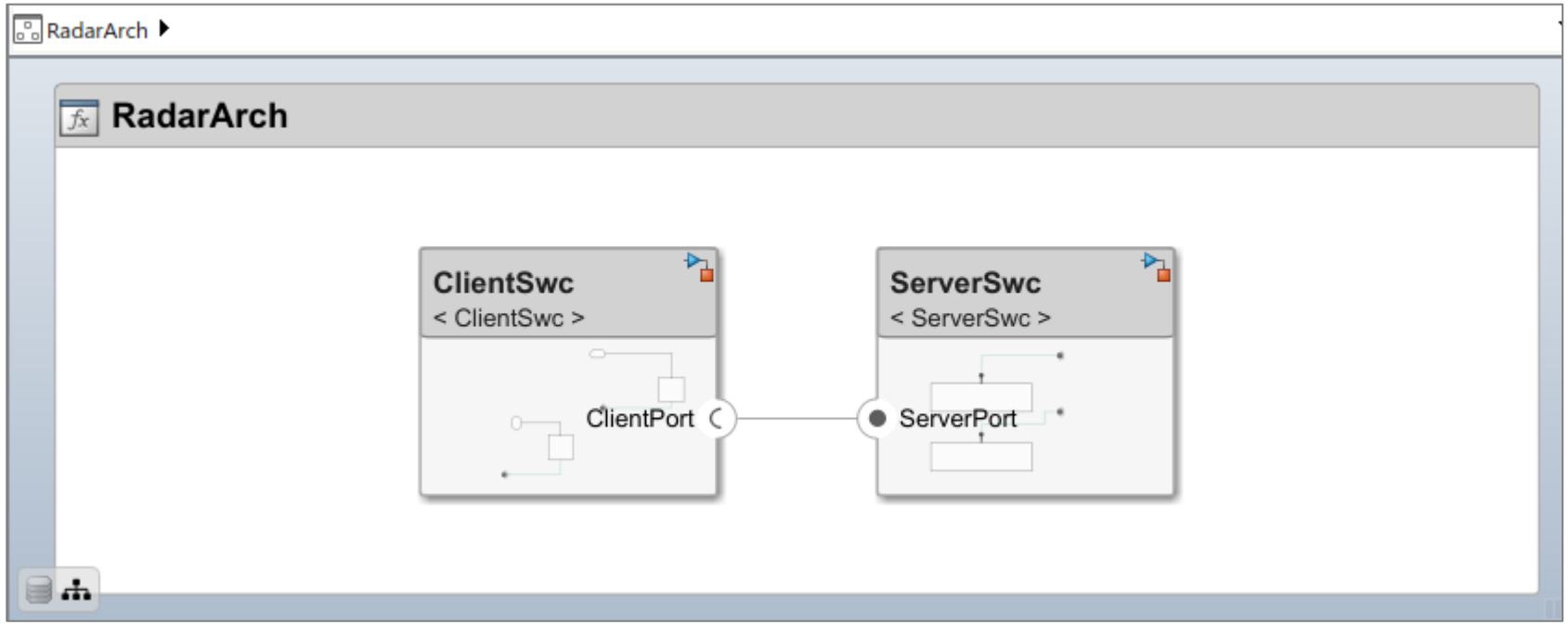
- New blocks to process messages by executing subsystem when message is available
- Model and generate code for components that are executed on message arrival

Function Ports for SOA



Model client and server components to facilitate data sharing using a functional interface between component models

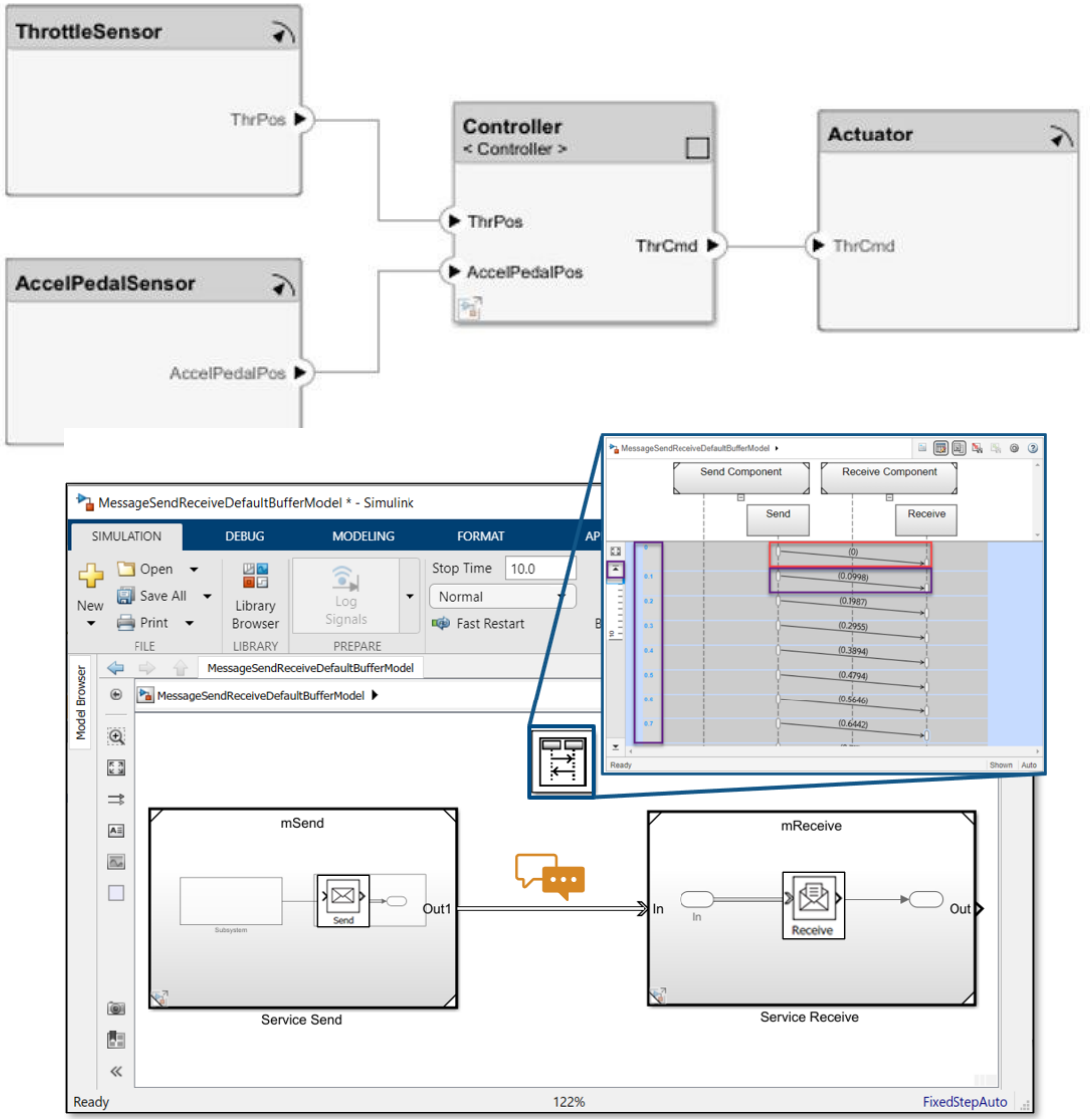
Author SOA applications in software architecture models



Model client-server connections between software components in software architectures in System Composer

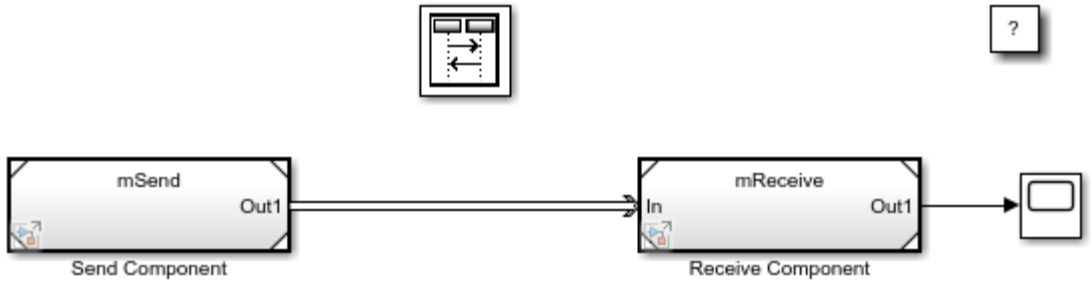
MathWorks investments in **SW architecture design** and **simulation**

- Intuitive, collaborative, graphical environment to design **software architectures**
  - Manage complexity
  - Maximize sharing and reuse
- High-level language to model and simulate **service-oriented applications**
  - Messages and queues
  - Client / server relationship
  - Sequence diagrams



Deploying SOA using C++

Generate SOA-based C and C++ application code from software services modeled in Simulink for deployment.




```
// Forward declaration
class MessageSendReceiveDefaultBufferModelModelClass;
class
  MessageSendReceiveDefaultBufferModelModelClassMessa_ReceiveComponent_RecvDataT
  : public RecvData_real_T
{
 private:
  MessageSendReceiveDefaultBufferModelModelClass & aProvider;
 public:
  MessageSendReceiveDefaultBufferModelModelClassMessa_ReceiveComponent_RecvDataT
    (MessageSendReceiveDefaultBufferModelModelClass & aProvider);
  virtual void RecvData(real_T *data, int32_T length, int32_T *status);
};

class
  MessageSendReceiveDefaultBufferModelModelClassMessa_ReceiveComponent_SendDataT
  : public SendData_real_T
{
 private:
  MessageSendReceiveDefaultBufferModelModelClass & aProvider;
 public:
  MessageSendReceiveDefaultBufferModelModelClassMessa_ReceiveComponent_SendDataT
    (MessageSendReceiveDefaultBufferModelModelClass & aProvider);
  virtual void SendData(const real_T *data, int32_T length, int32_T *status);
};
```


```
// Constructor
MessageSendReceiveDefaultBufferModelModelClass::
  MessageSendReceiveDefaultBufferModelModelClass():
  MessageSendReceiveDefaultBuff_B()
  ,MessageSendReceiveDefaultBuf_DW()
  ,ReceiveComponentRecvData(*this)
  ,SendComponentSendData(*this)
  ,Receive_ComponentMDLOBJ0(get_ReceiveComponentRecvData())
  ,Send_ComponentMDLOBJ1(get_SendComponentSendData())
  ,MessageSendReceiveDefaultBuf_M()
{
  // Currently there is no constructor body generated.
}
```

[>> Generate C++ Messages to Communicate Data Between Simulink Components]

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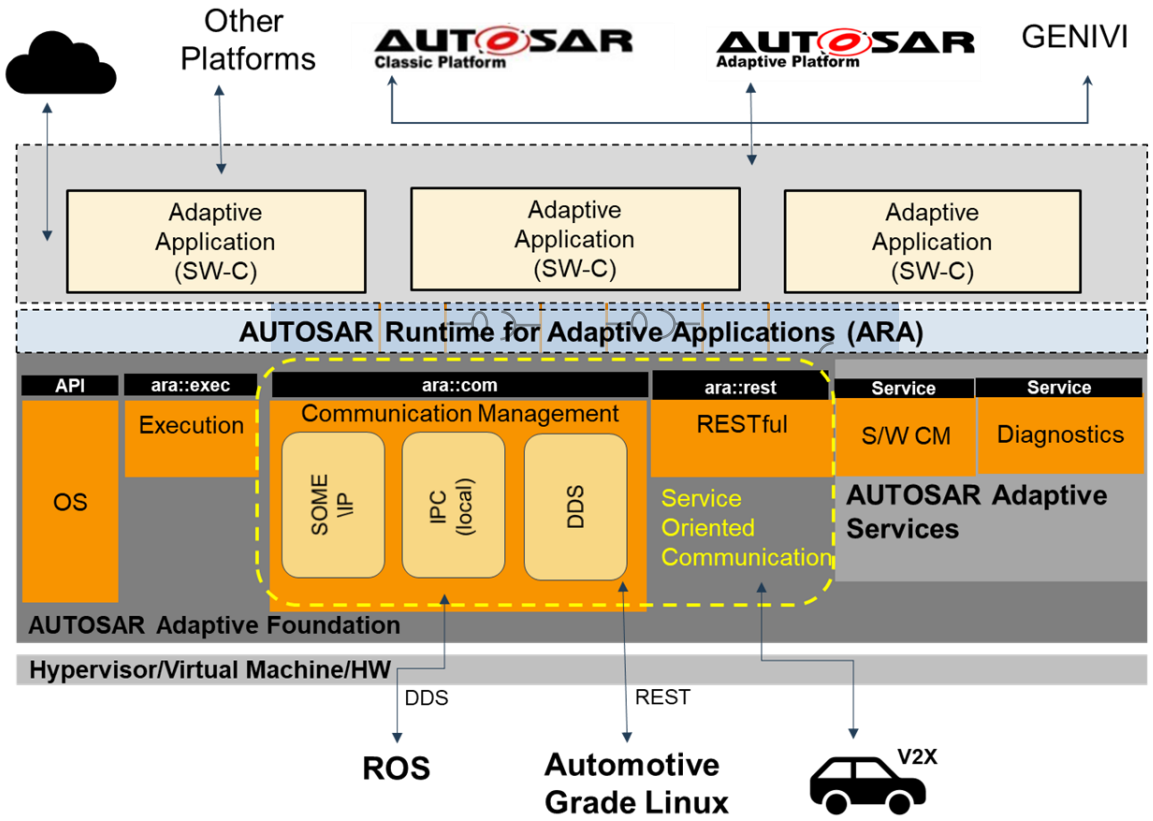
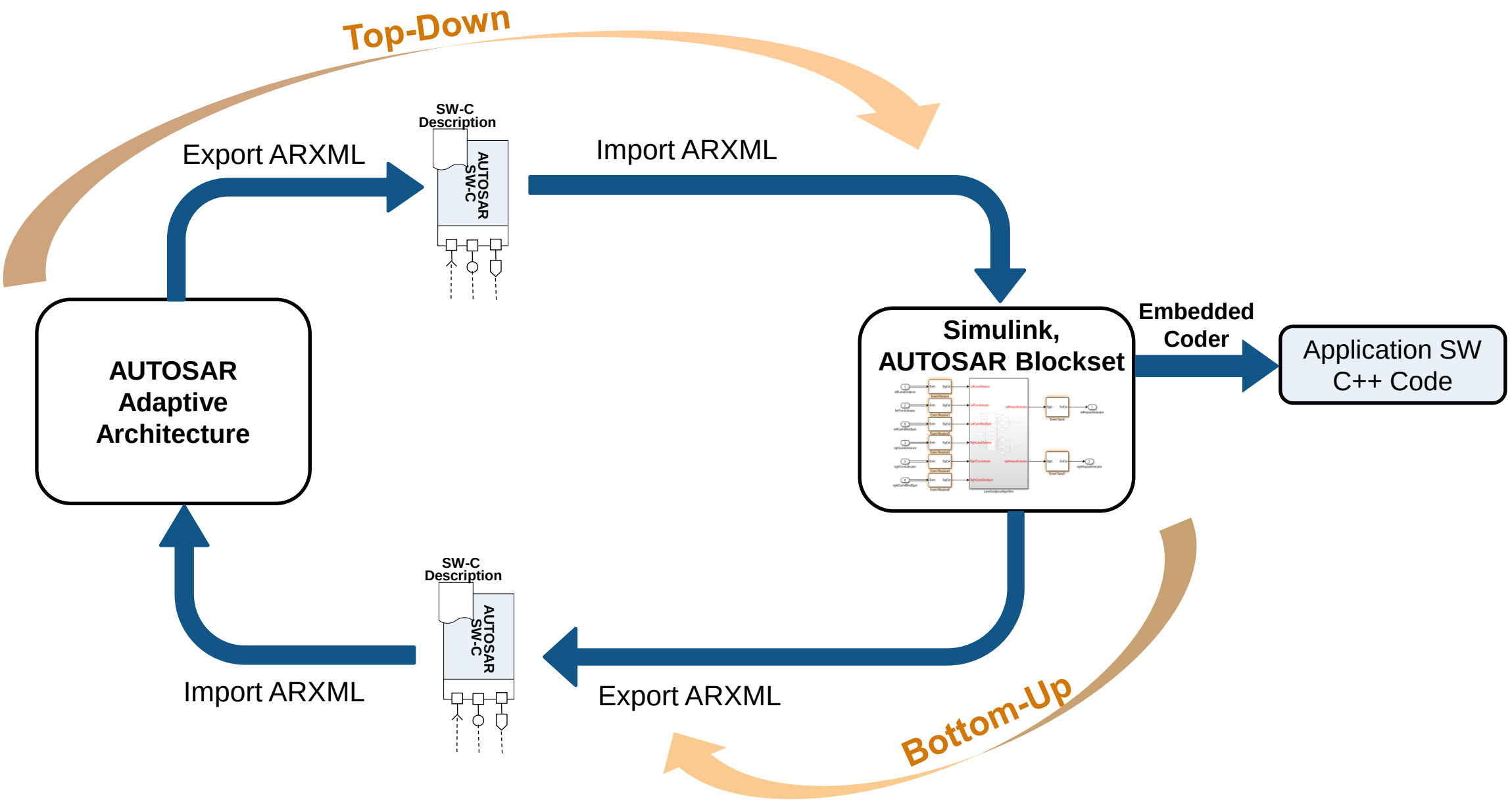
AUTOSAR Adaptive

AUTOSAR Adaptive Platform implements the AUTOSAR Runtime for Adaptive Applications (ARA) for automotive industry.

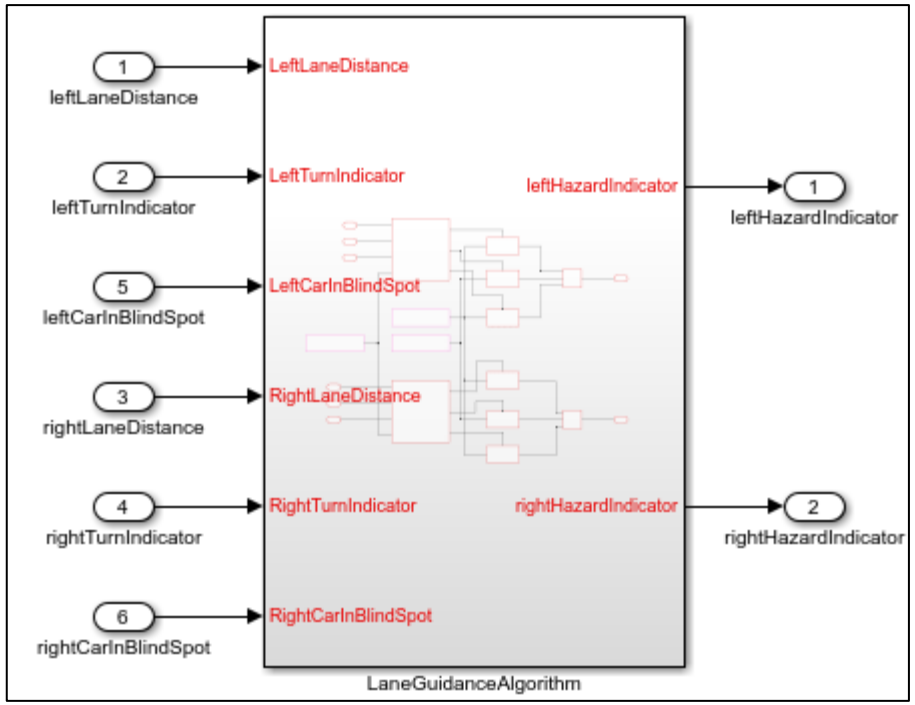


AUTOSAR Adaptive workflows



AUTOSAR Adaptive in action

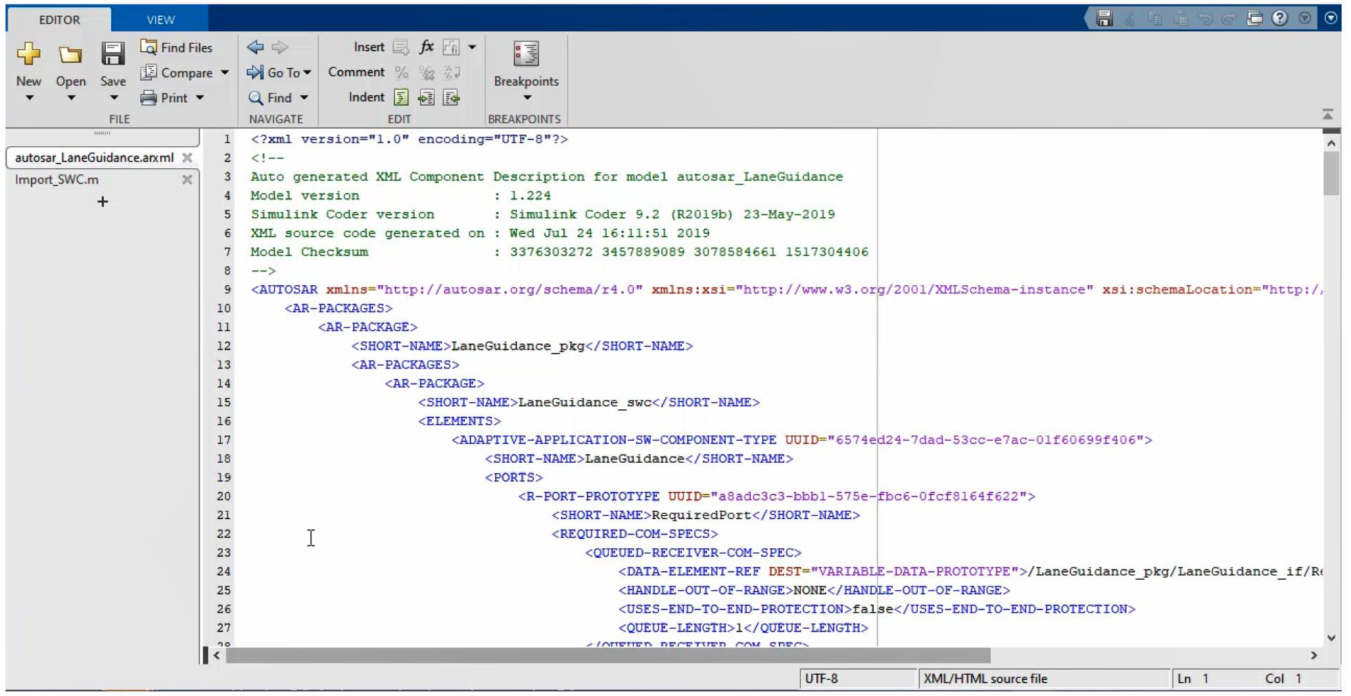
Legacy Simulink model



Bottom-Up

OR

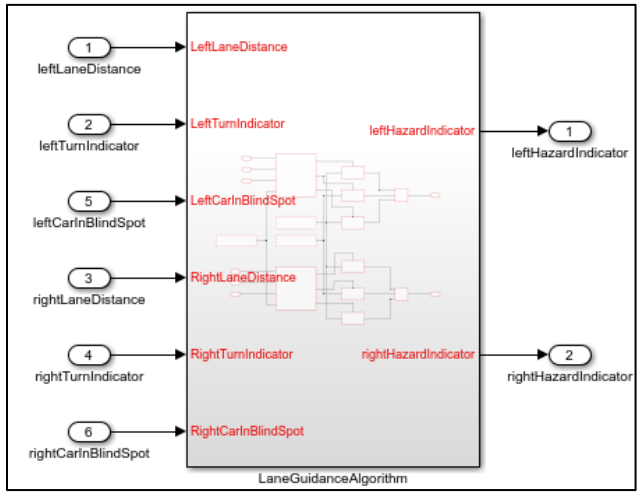
Start from an AUTOSAR Adaptive ARXML

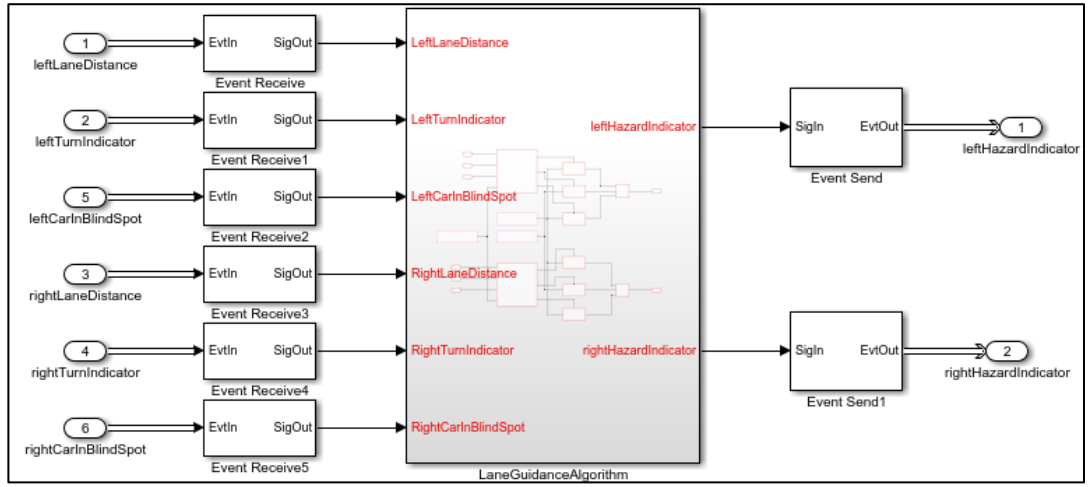


Top-Down

AUTOSAR Adaptive in action: bottom-up

Add blocks to make the necessary event and signal connections





Add Message ports and Message-Signal conversion blocks

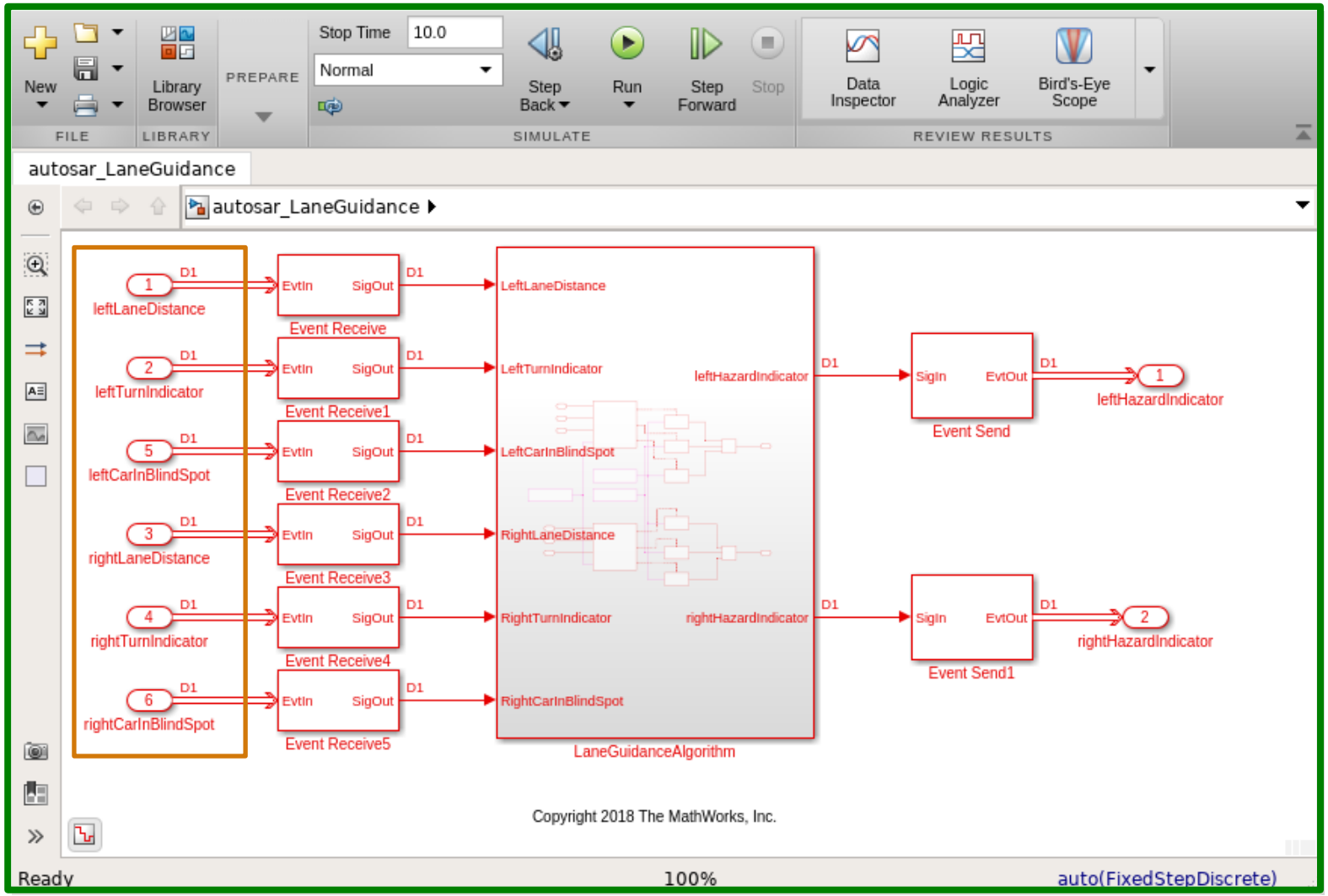
Modelling an AUTOSAR Adaptive application in Simulink

AUTOSAR

Adaptive Application

RequiredPort

```
"Radar" : {
    // events
    "event" : {
        "leftLaneDistance"
        "leftTurnIndicator"
        "leftCarInBlindSpot"
        "rightLandDistance"
        "rightTurnIndicator"
        "rightCarInBlindSpot"
    },
    // methods
    "method" : {
        "Calibrate"
        "Adjust"
    },
    // fields
    "field" : {
        "updateRate"
    }
}
```



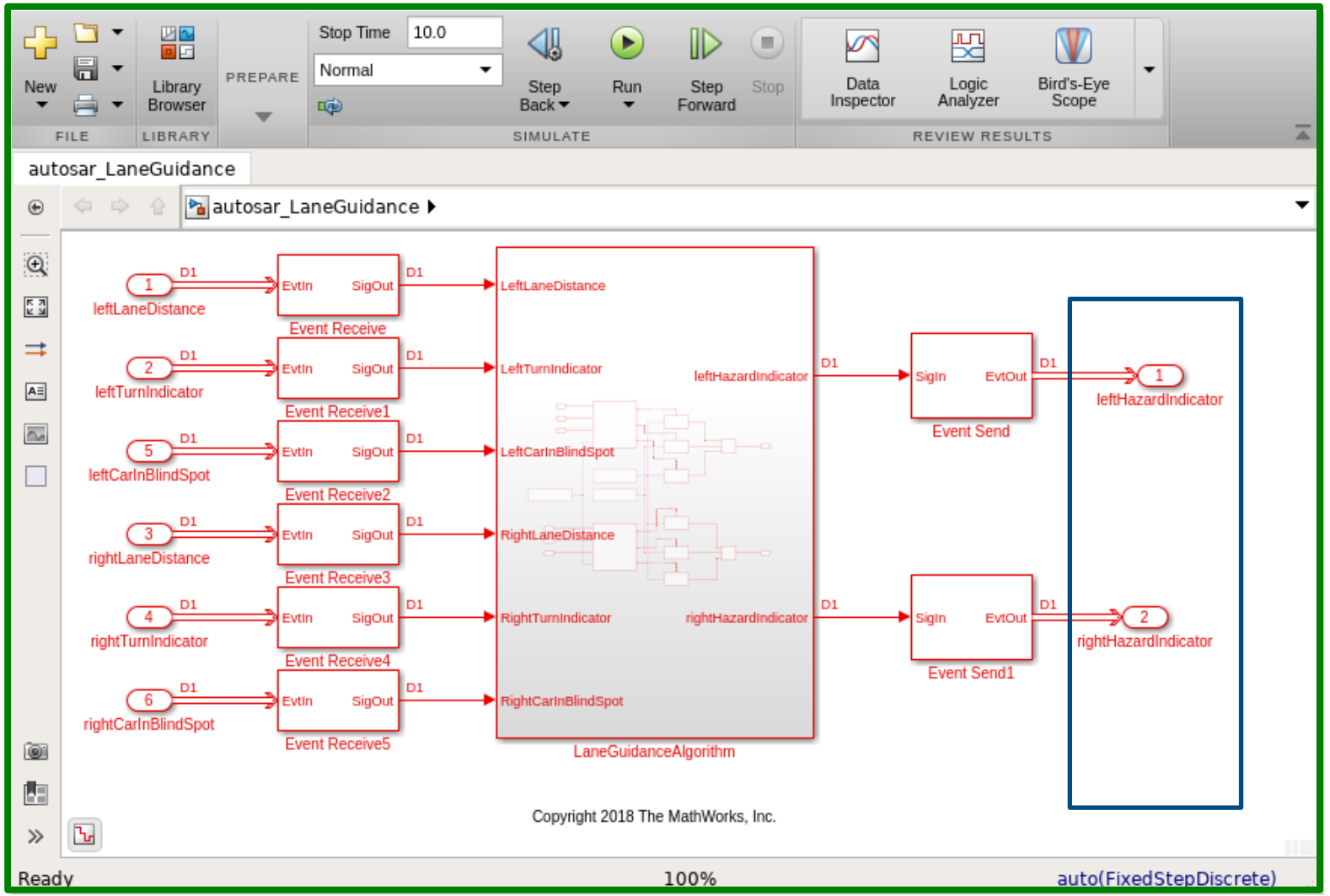
Modelling an AUTOSAR Adaptive application in Simulink

AUTOSAR

Adaptive Application

ProvidedPort

```
"Hazard" : {
    // events
    "event" : {
        "leftHazardIndicator"
        "rightHazardIndicator"
    },
    // methods
    "method" : { },
    // fields
    "field" : { }
}
```



Modelling an AUTOSAR Adaptive application in Simulink

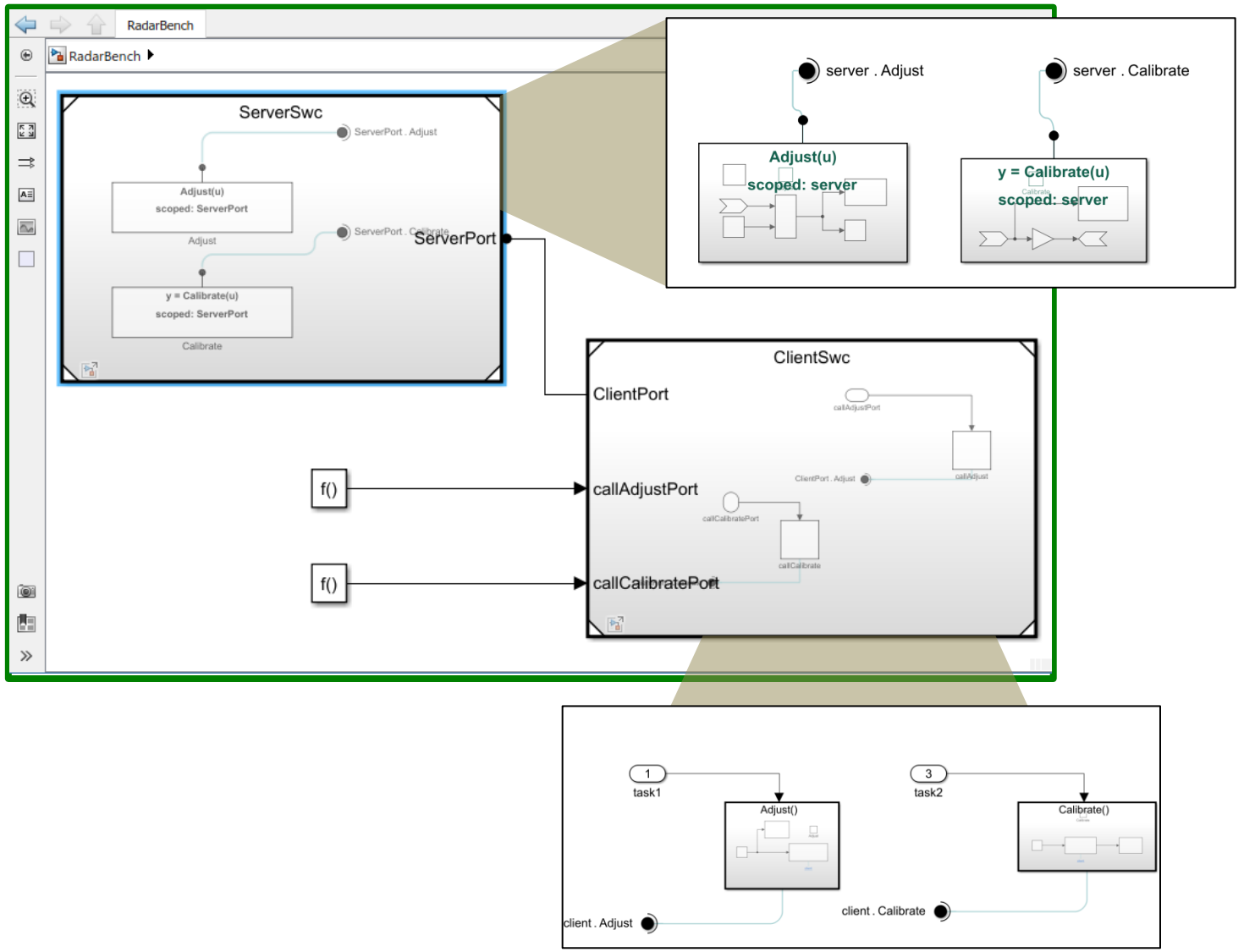
AUTOSAR

Client

Adaptive Application

Server

```
"Hazard" : {
    // events
    "event" : { },
    // methods
    "method" : {
        "calibrate"
        "adjust"
    },
    // fields
    "field" : { }
}
```

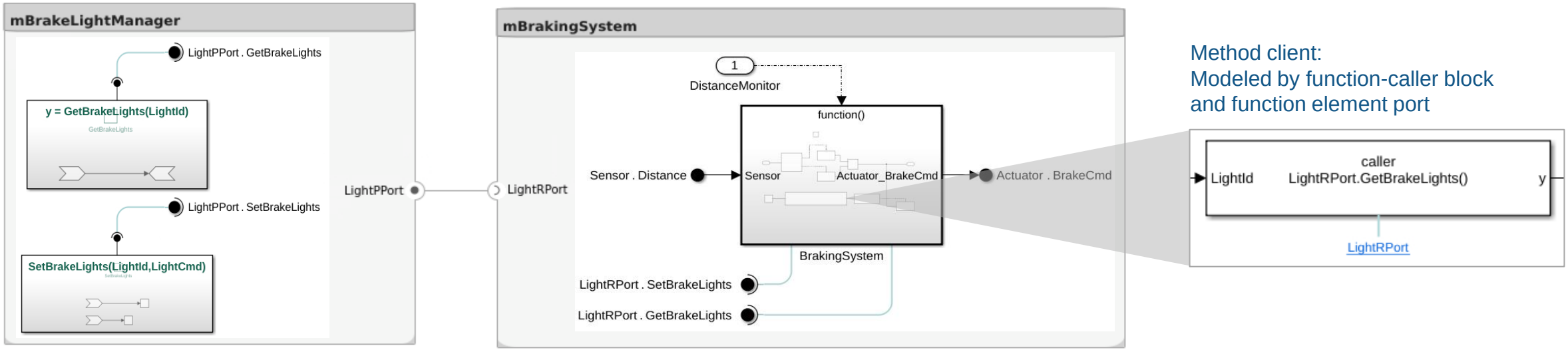


Model synchronous/blocking methods

- Use case
  - Client needs method results to proceed
  - Blocks on method call
- Simulink supports modelling of methods
  - Blocking Request-Response methods
  - Fire-Forget Methods

Client Pseudo-code:

```
void mBrakingSystem::DistanceMonitor()
{
  ...
  auto GetBrakeLightsFuture = LightRPort->GetBrakeLights(1);
  auto GetBrakeLightsResult = GetBrakeLightsFuture.GetResult();
  if (GetBrakeLightsResult.HasValue()) {
    GetBrakeLights::Output callOutput = GetBrakeLightsResult.Value();
    rtb_FunctionCaller1 = callOutput.y;
  }
  ...
}
```



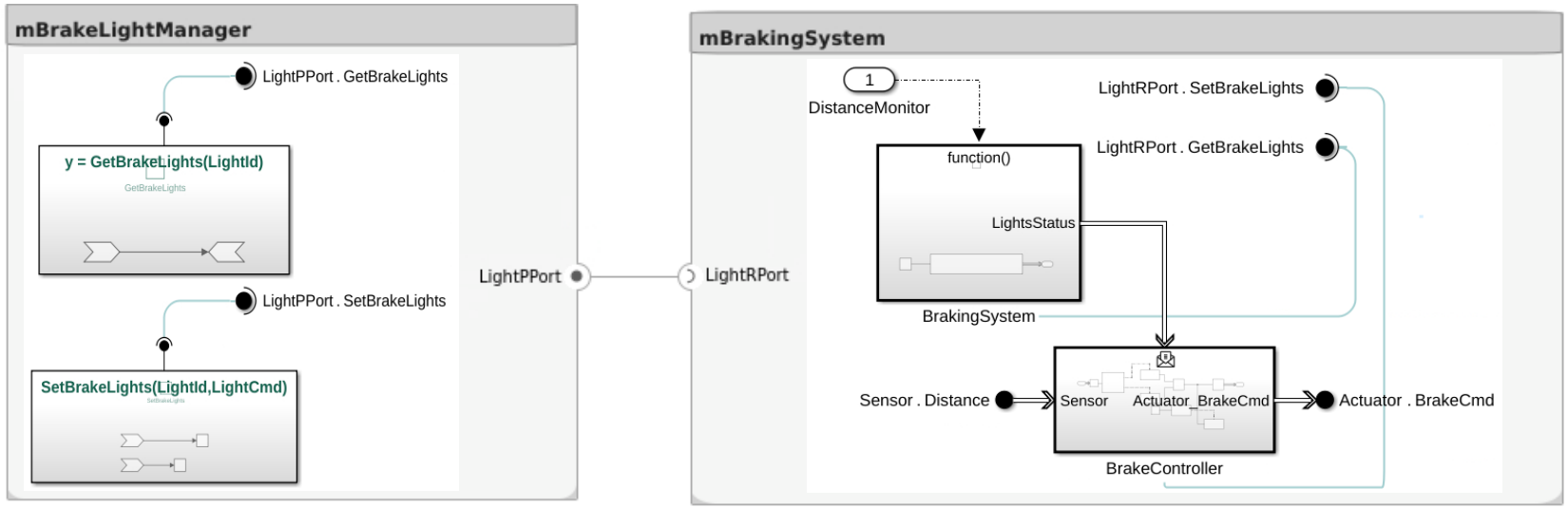
Model asynchronous/non-blocking methods

- Use case
  - Clients need not wait for method results
  - Register a call-back to process method output
- Simulink supports modelling of methods
  - Non-blocking Request-Response methods

Client Pseudo-code:

```
void mBrakingSystem::DistanceMonitor()
{
  ...
  auto GetBrakeLightsFuture = LightRPort->GetBrakeLights(1);
  auto callbackGetBrakeLightsFuture = GetBrakeLightsFuture.then(
      &mAsyncBrakingSystem::GetBrakeLightsCallback);
  ...
}
```

Method call and callback registration

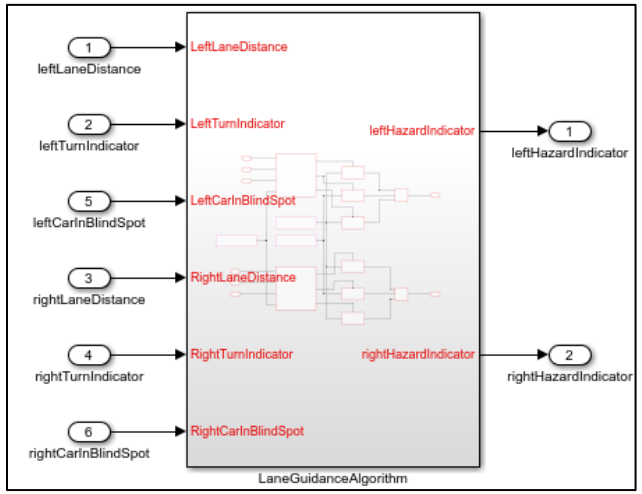


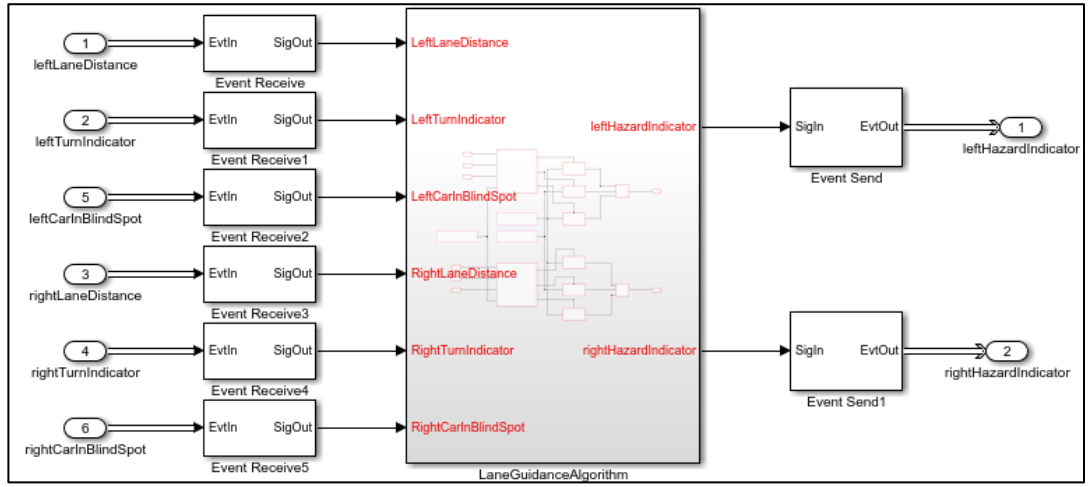

```
void mAsyncBrakingSystem::GetBrakeLightsCallback(
  ara::core::Future<GetBrakeLights::Output>
futureObj)
{
  auto GetBrakeLightsResult = futureObj.GetResult();
  if (GetBrakeLightsResult.HasValue()) {
    GetBrakeLights::Output callOutput =
        GetBrakeLightsResult.Value();
    BrakeController(callOutput.y);
  }
}
```

Method callback body

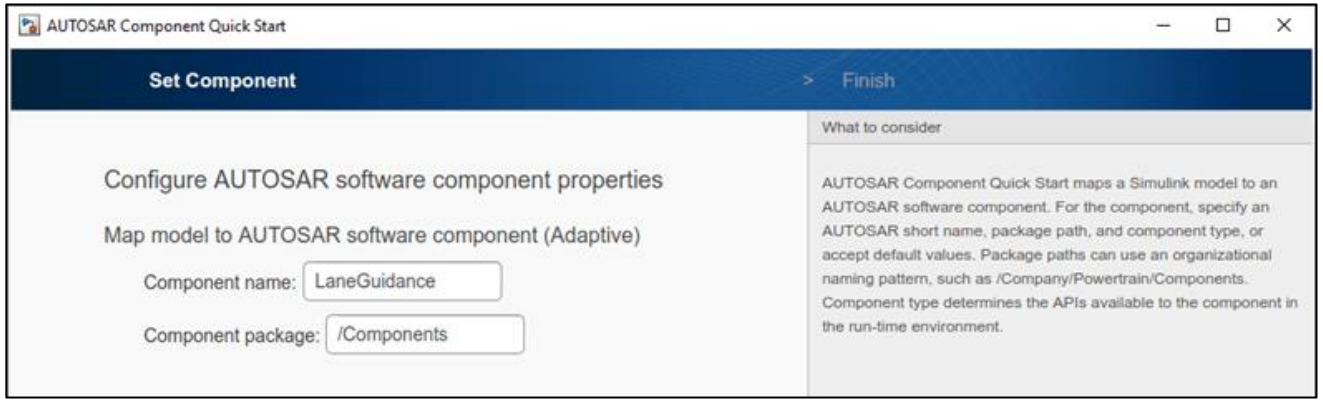
AUTOSAR Adaptive in action: bottom-up

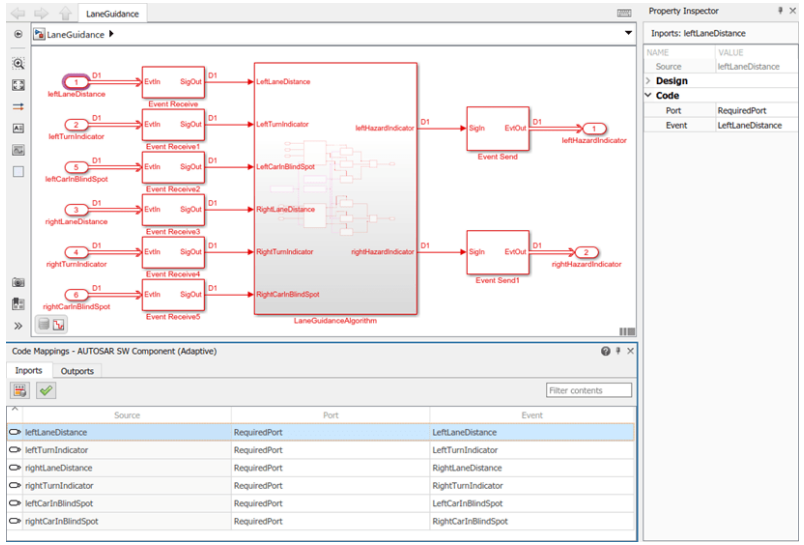
Add blocks to make the necessary event and signal connections





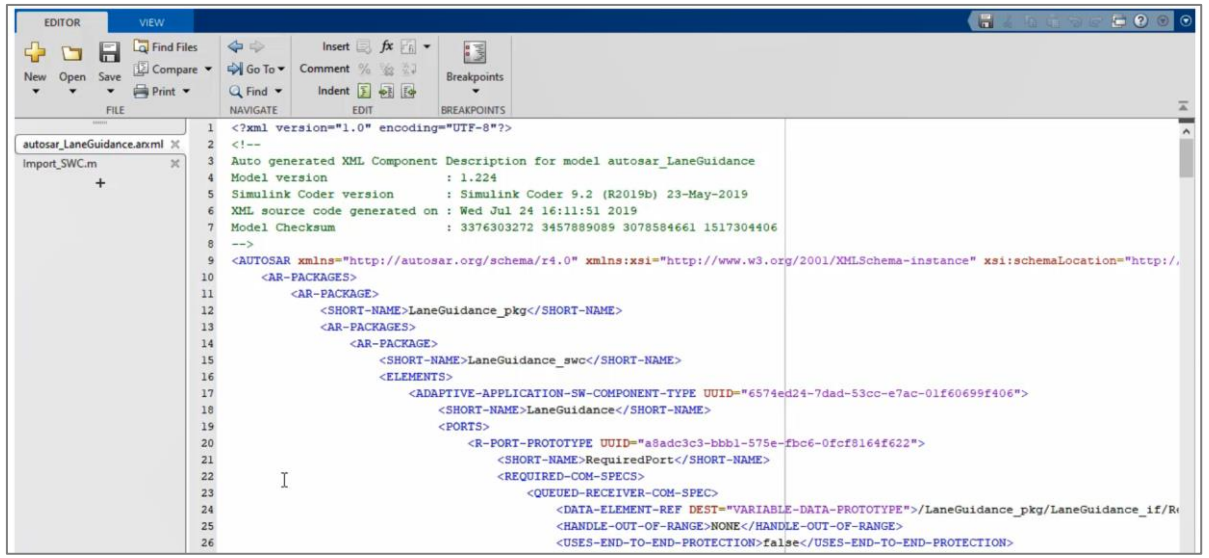
AUTOSAR Quick Start





AUTOSAR Adaptive in action: top-down

- Create model from ARXML

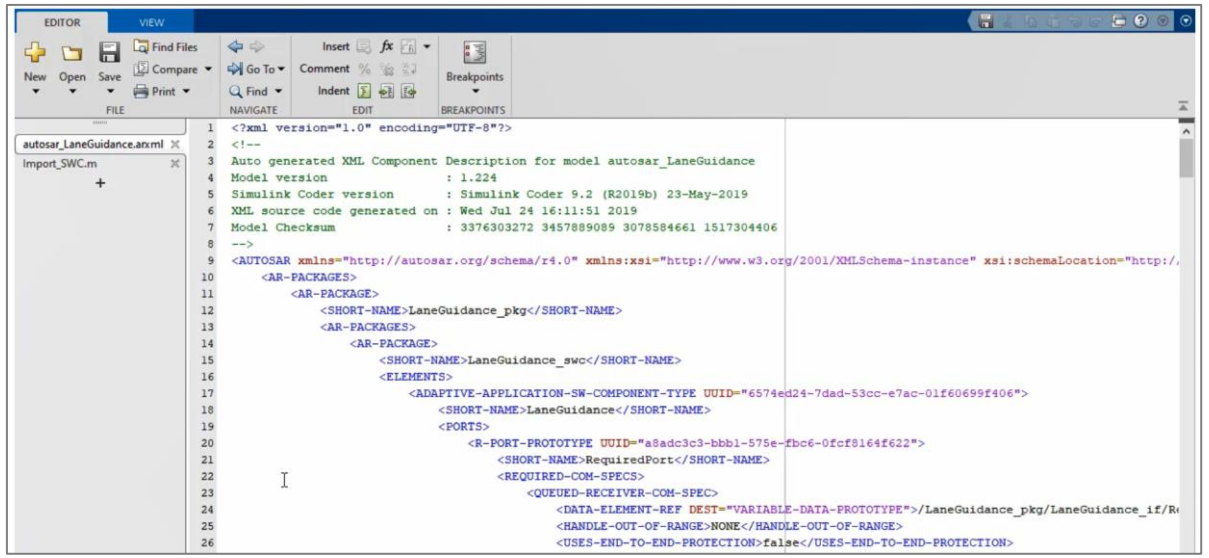


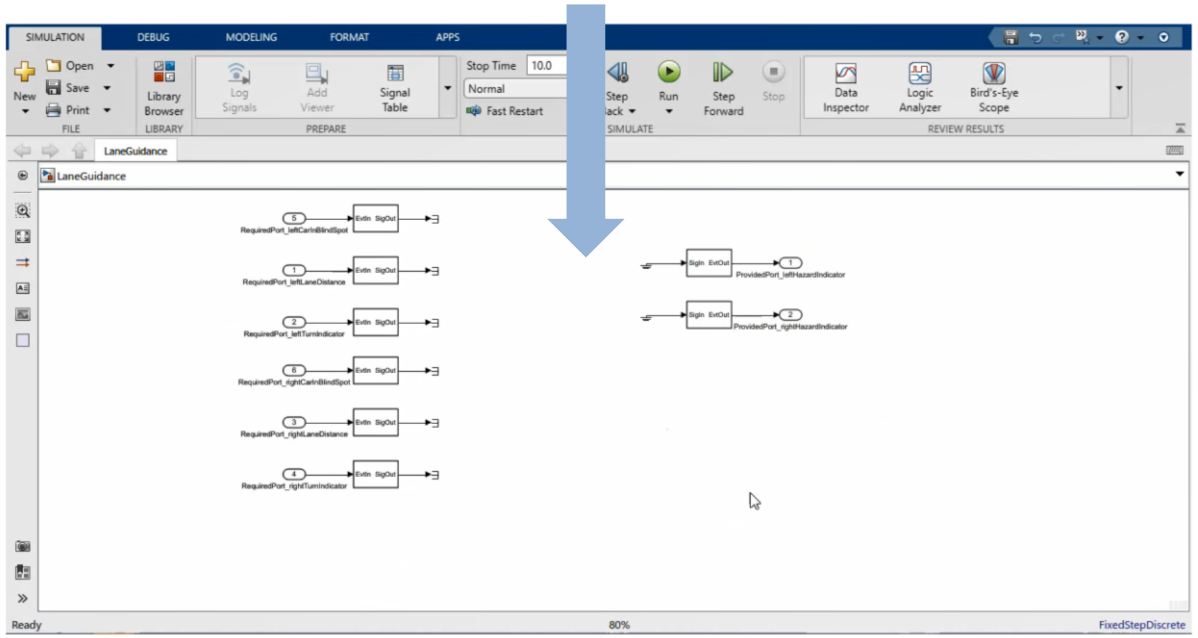

```
ar = arxml.importer({'fusion_app.arxml','radarService_app_mod.arxml','radar_svc_mod.arxml','stdtypes_mod.arxml'});
names = getComponentNames(ar)
```

AUTOSAR Adaptive in action: top-down

- Create model from ARXML

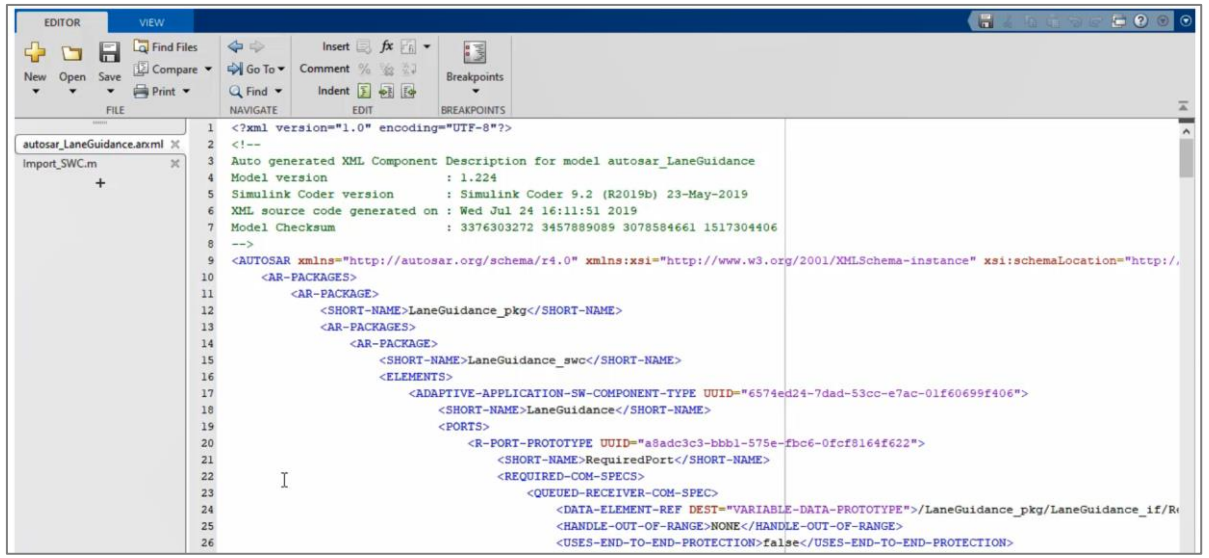
```
createComponentAsModel(ar,'/RadarFusion/fusion');
```

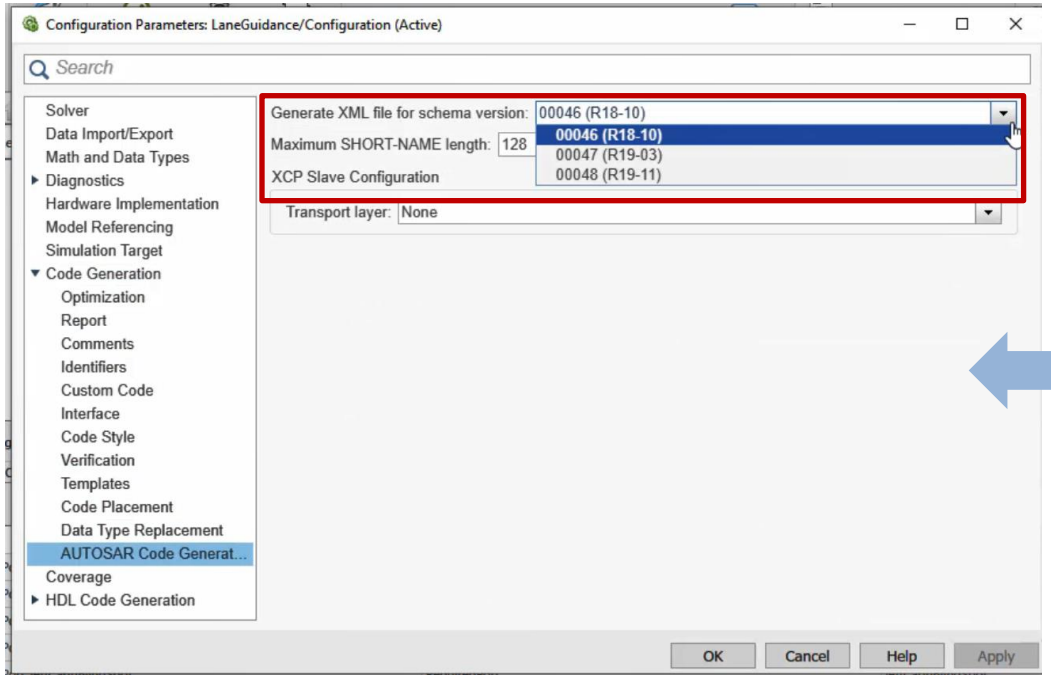


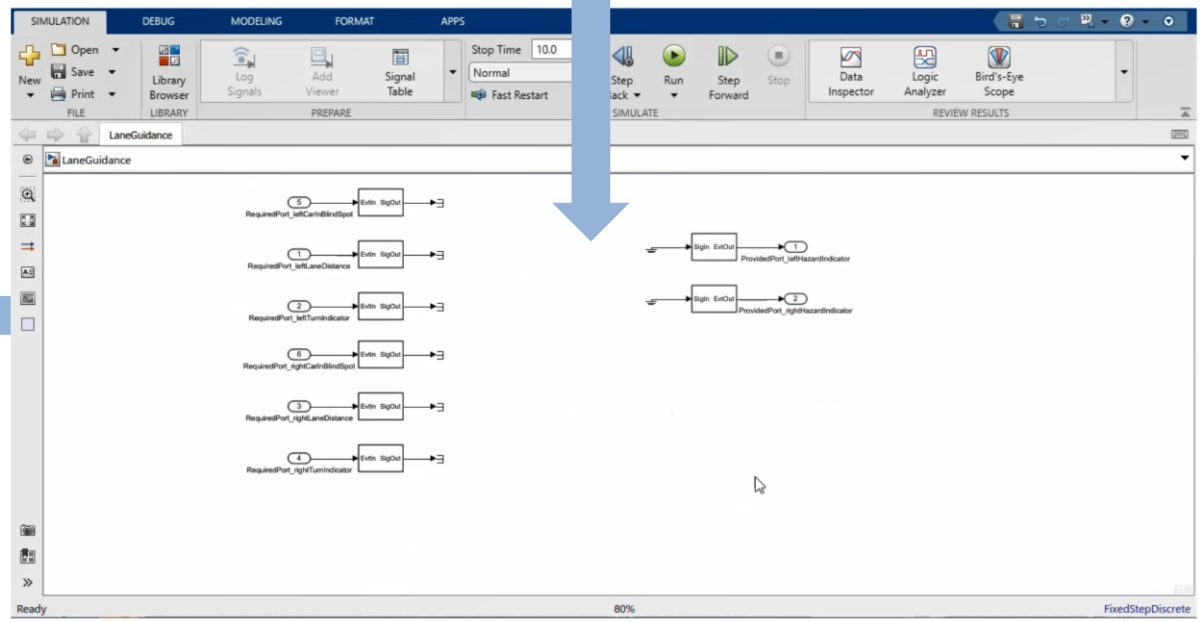


AUTOSAR Adaptive in action: top-down

- Create model from ARXML

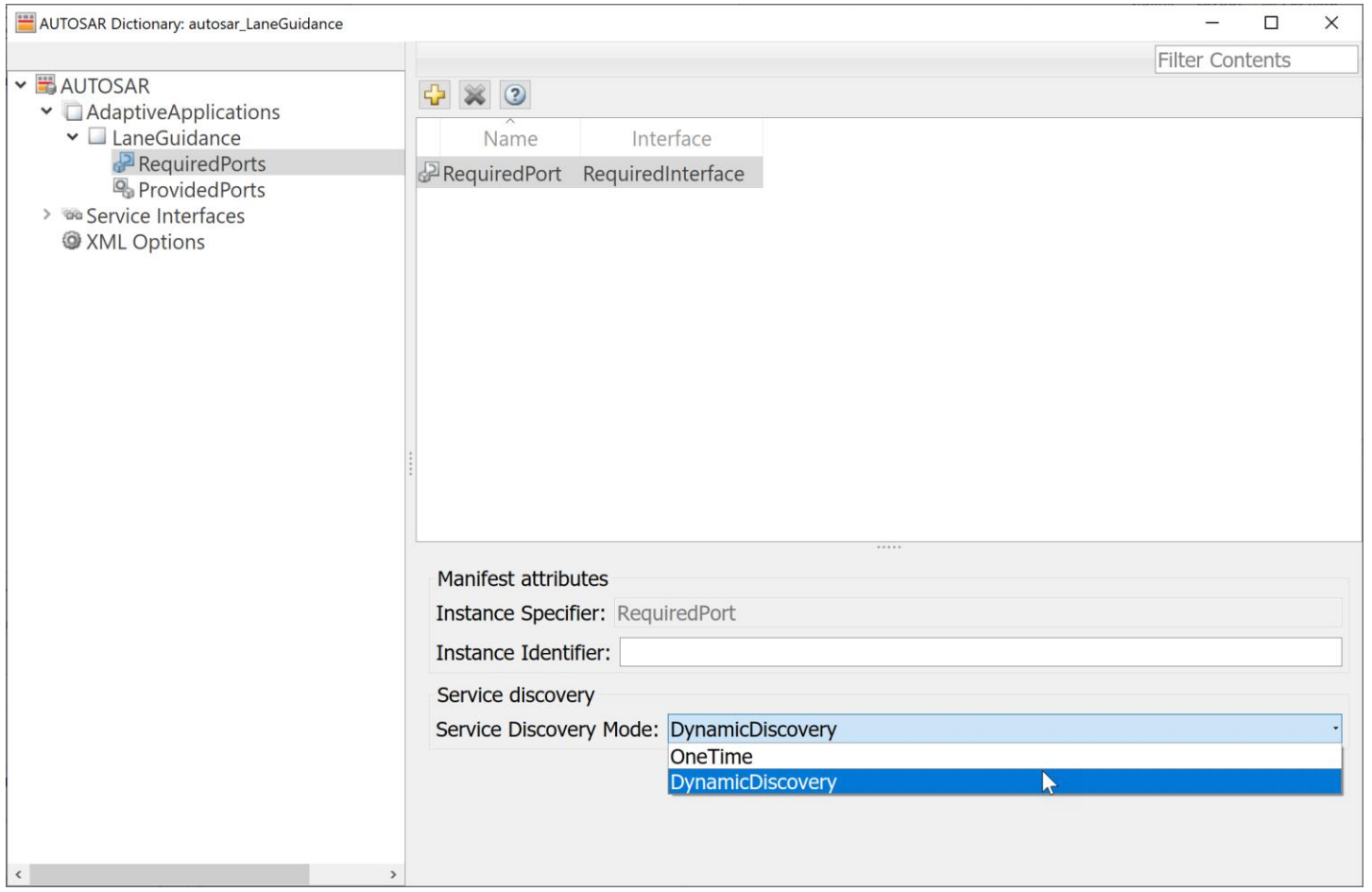






AUTOSAR Adaptive in action: top-down

- Create model from ARXML
- Configure Service Discovery



AUTOSAR Adaptive in action: top-down

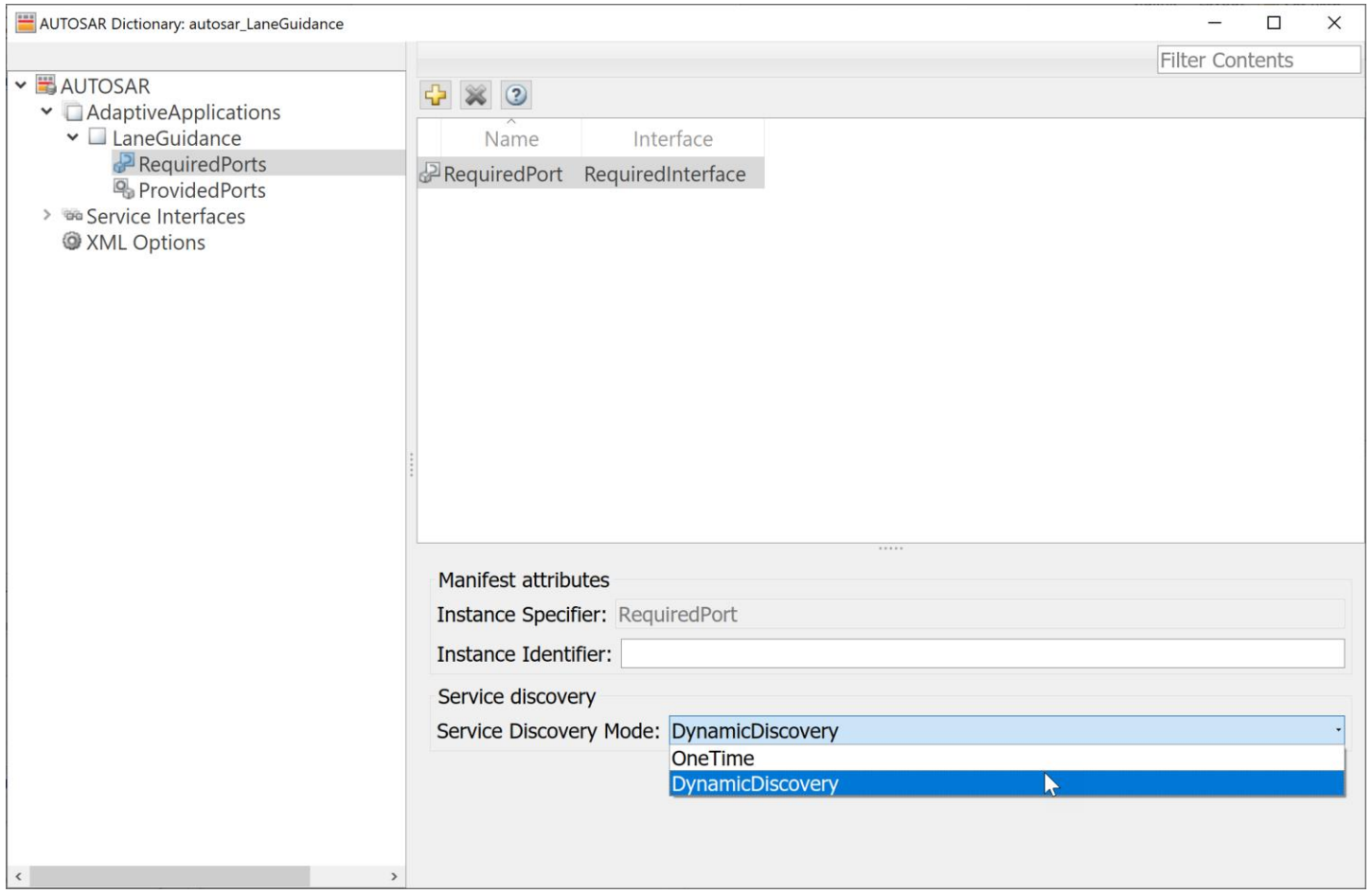
- Create model from ARXML

- Configure Service Discovery

  Subscribe to adaptive services

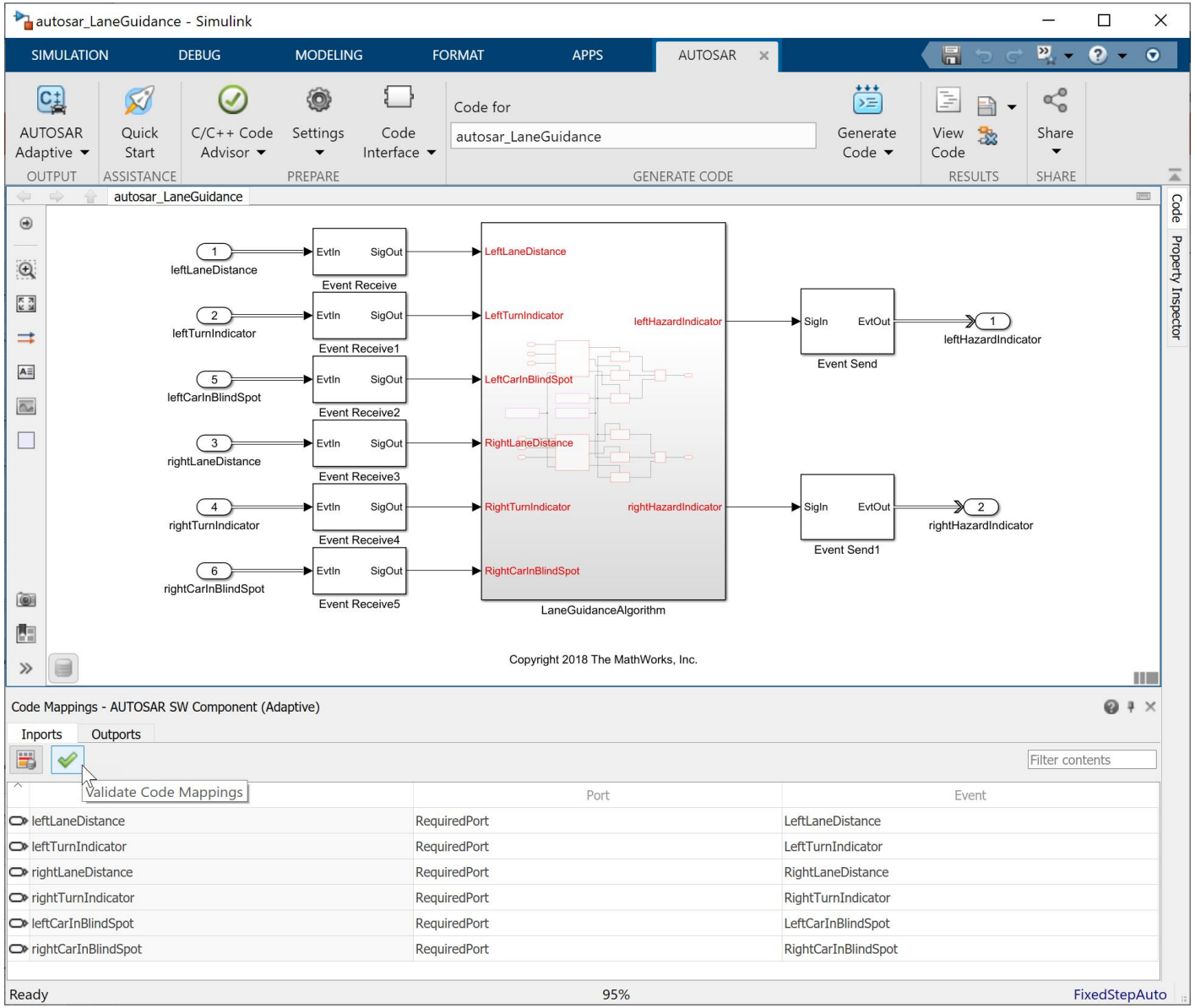
  – Only at startup, or

  – Dynamically, as they become available



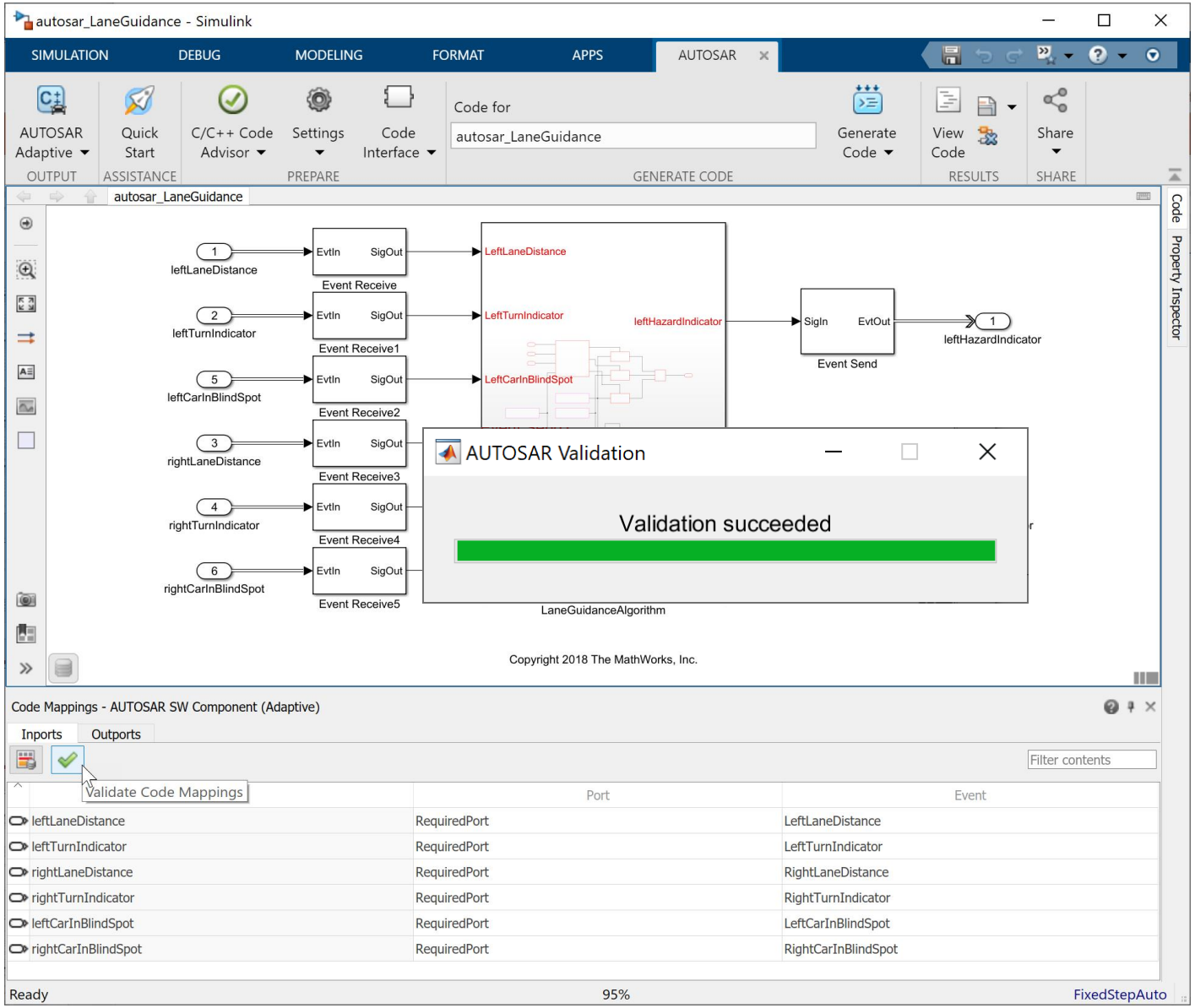
AUTOSAR Adaptive in action: top-down

- Create model from ARXML
- Configure Service Discovery
- Verify AUTOSAR properties



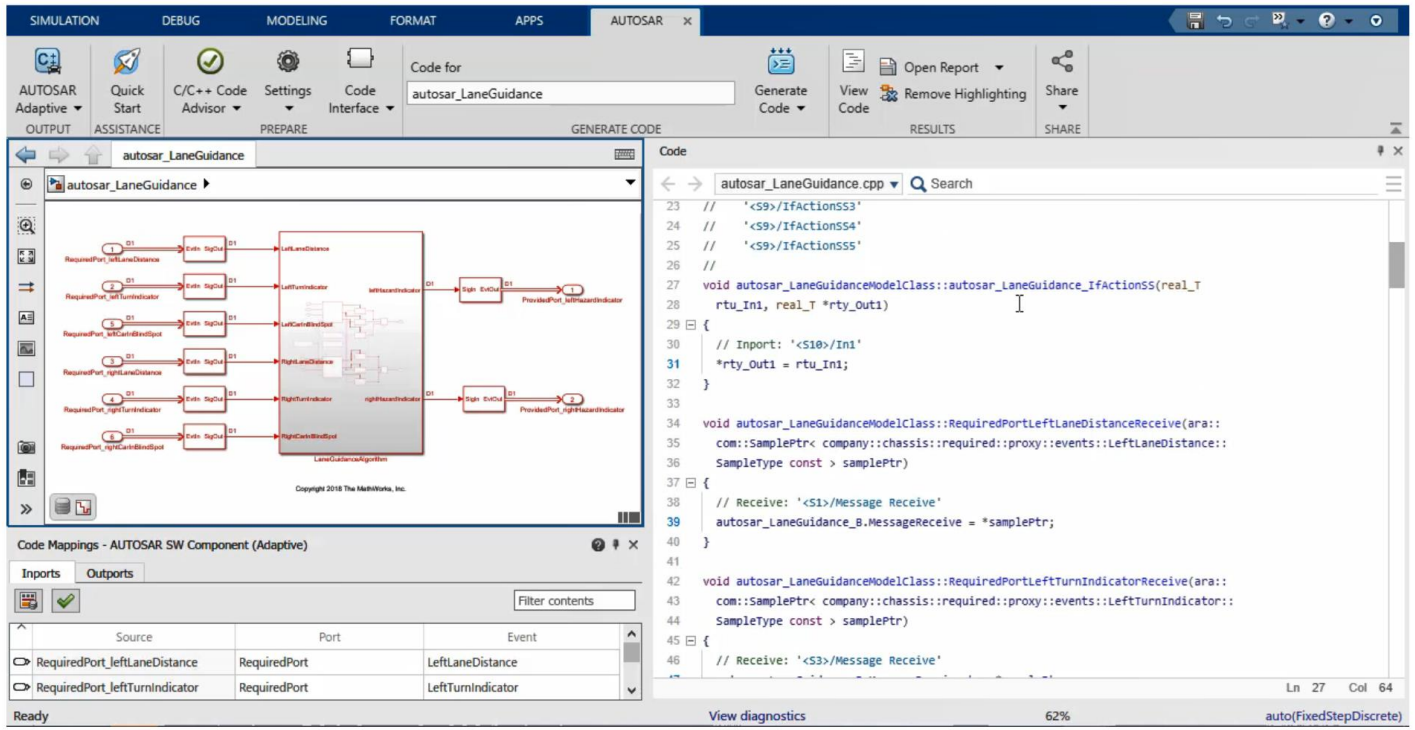
AUTOSAR Adaptive in action: top-down

- Create model from ARXML
- Configure Service Discovery
- Verify AUTOSAR properties



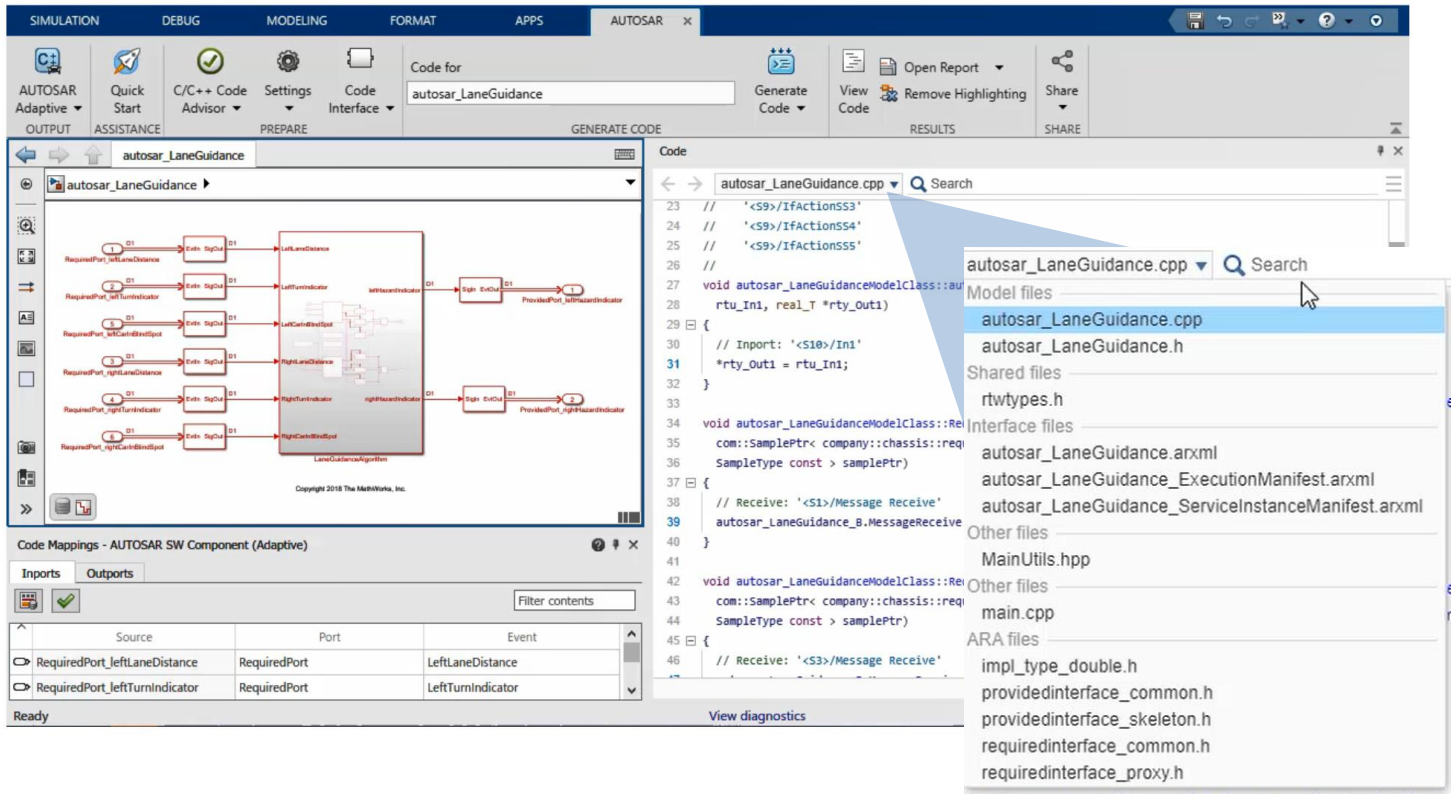
AUTOSAR Adaptive in action: top-down

- Create model from ARXML
- Configure Service Discovery
- Verify AUTOSAR properties
- Generate code



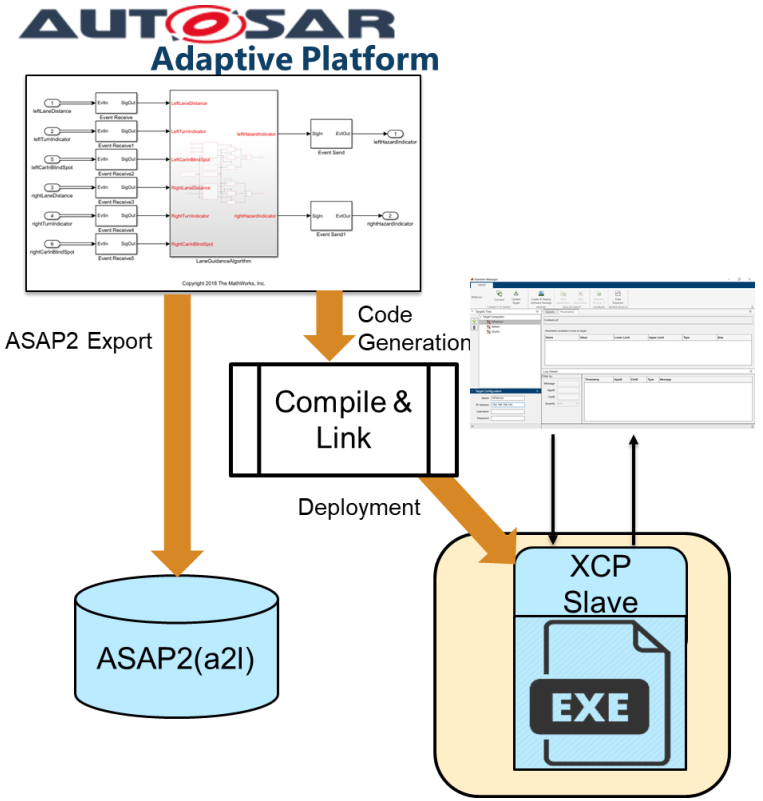
AUTOSAR Adaptive in action

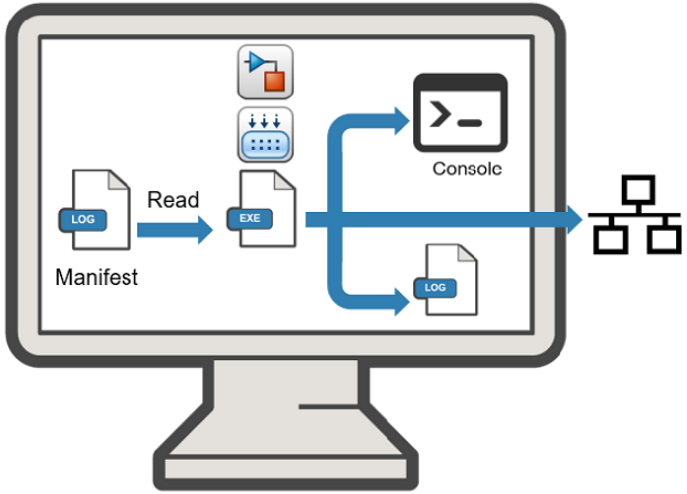
- Create model from ARXML
- Configure Service Discovery
- Verify AUTOSAR properties
- Generate code
  - Integrate Applications with third-party Adaptive stack
  - Create Linux executables for calibration and monitoring



AUTOSAR Adaptive Deployment

- Create Linux executables for Run-Time Calibration and Measurement
- Run-time logging (ara::log) for adaptive executables
  - Forward event logging information to a console, file, or network, as defined in the AUTOSAR Diagnostic Log and Trace specification





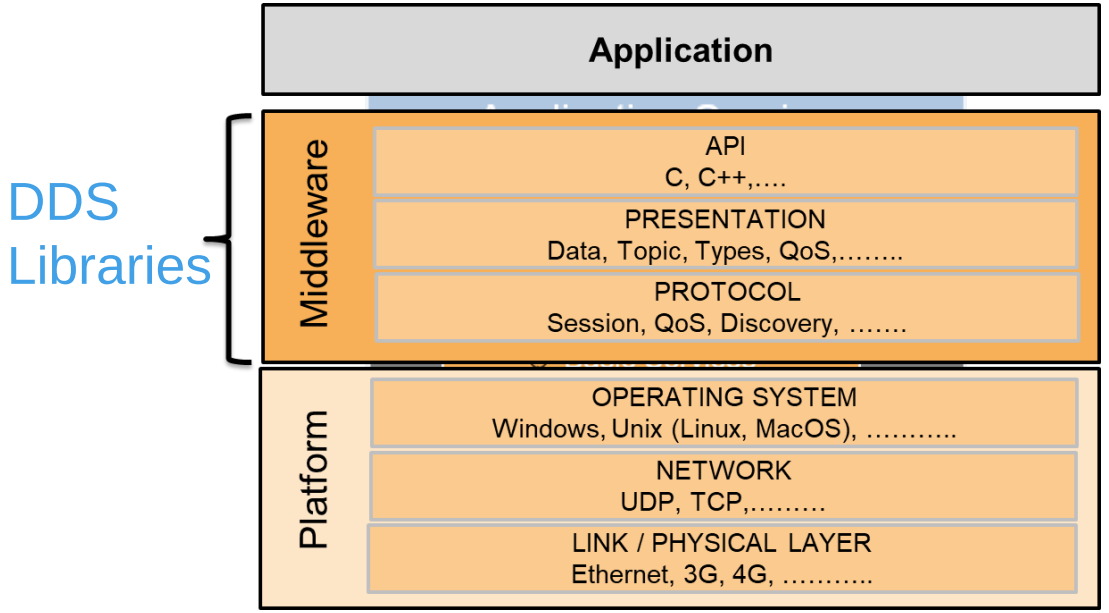
Agenda

- Software-defined vehicles and new architectures (SOA)
- SOA Concepts
- MathWorks Solutions for SOA
  - Adaptive AUTOSAR
  - DDS/ROS
- Conclusions and key takeaways

Simulink for DDS

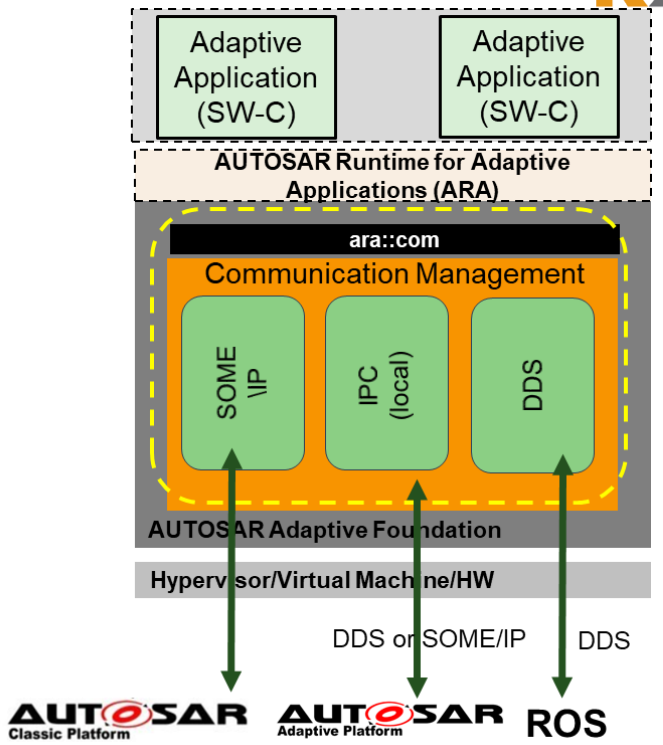
Data Distribution Services (DDS) uses SOA methodology, and directly addresses publish and subscribe communications for real-time and embedded systems.

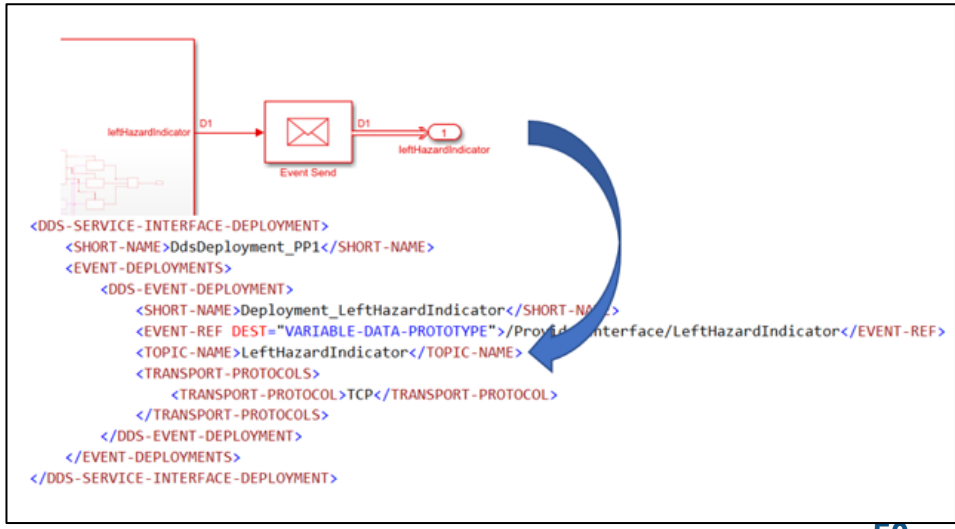
DDS addresses the needs of applications that require real-time data exchange in industries like aerospace and defense, automotive, and robotics.



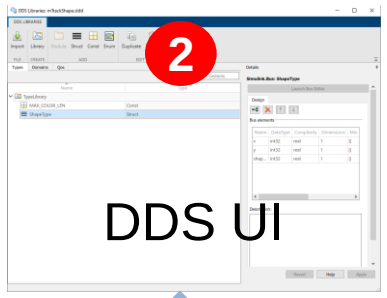
DDS (Data Distribution Services) is part of AUTOSAR Adaptive Deployment

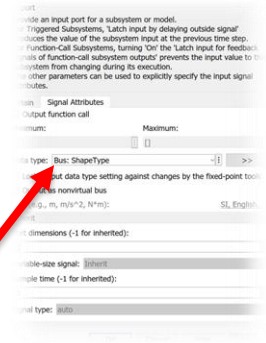
- Supports DDS binding for ara::com enabling communication between adaptive AUTOSAR applications
  - Generated `ServiceInstanceManifest.arxml` contains DDS deployment artifacts

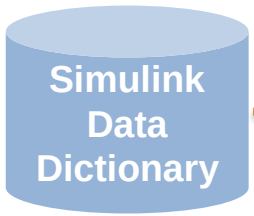




User Workflow with DDS Blockset

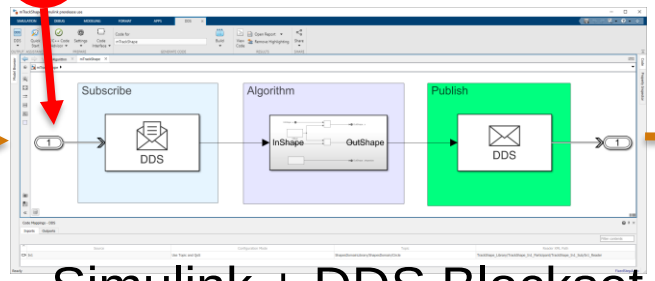






Import

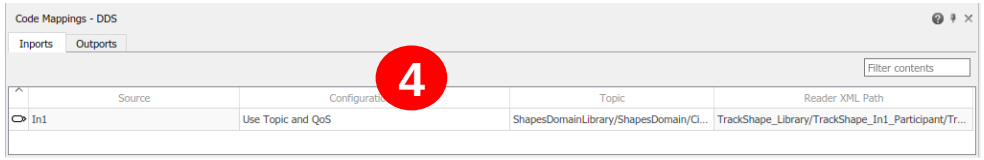
1



Simulink + DDS Blockset

5

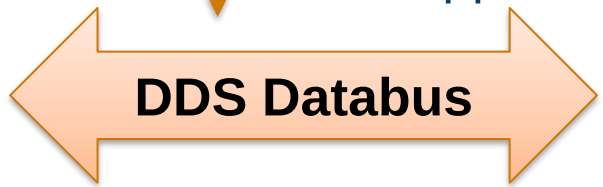
Generate

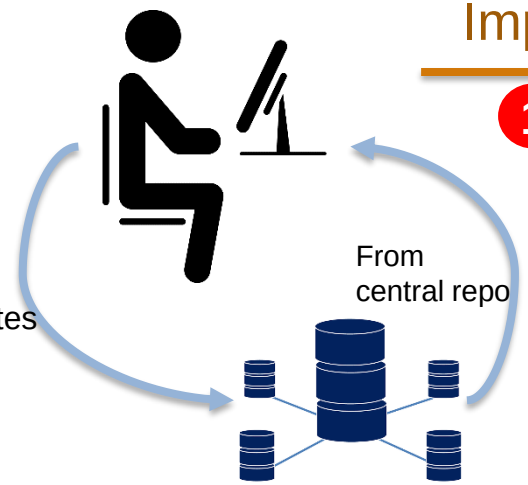


6

Deploy

IDL/XML
+
Vendor
support

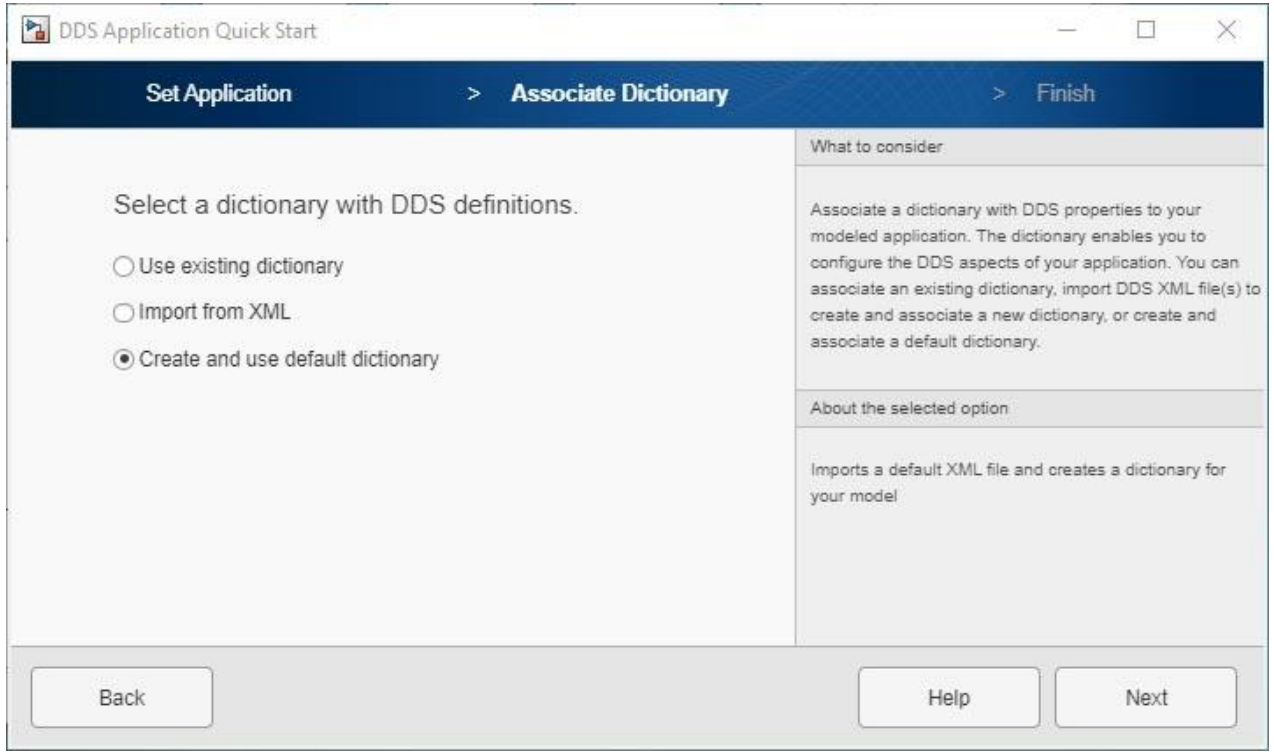




Interface definitions
QoS definitions
(XML)

DDS Blockset in action

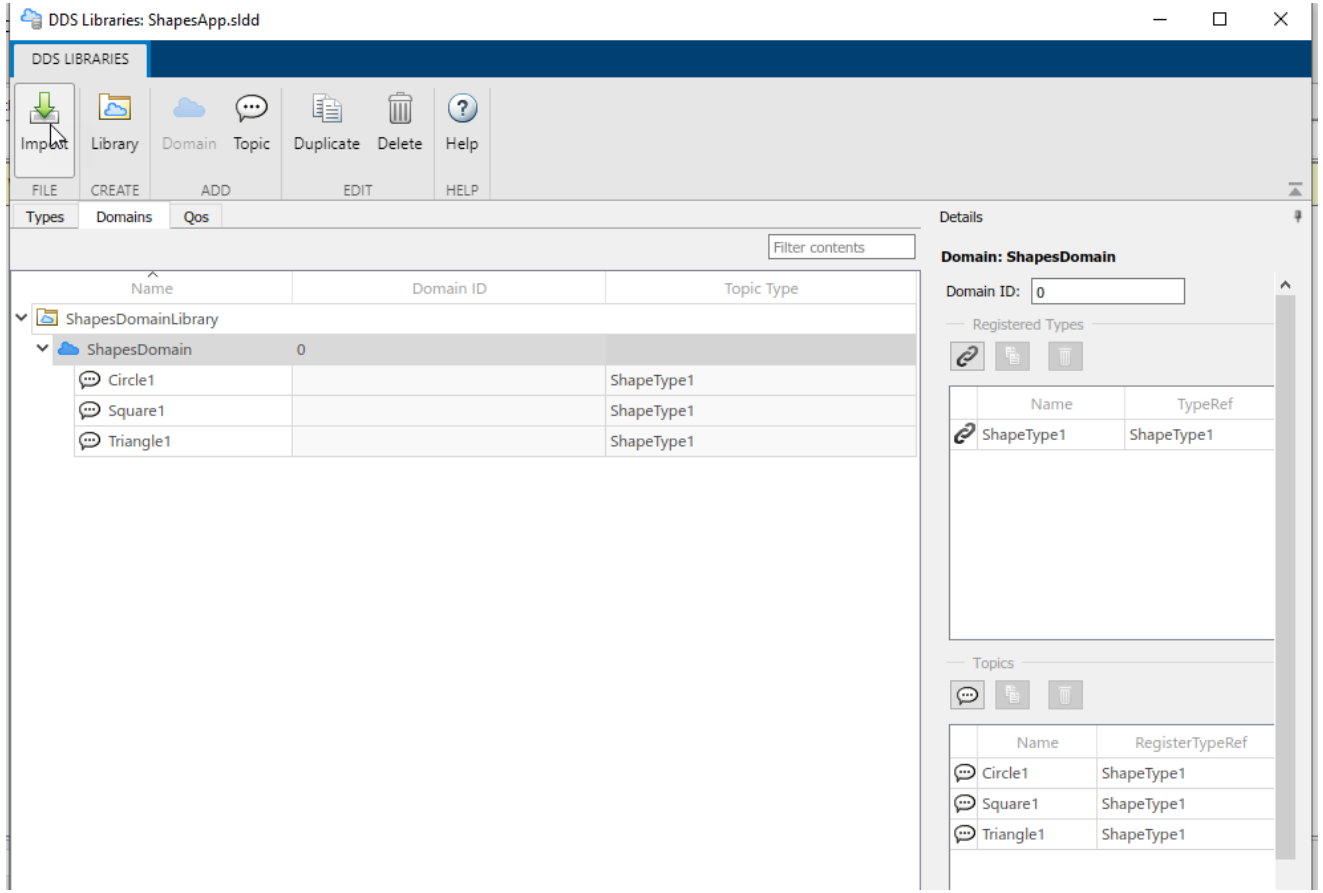
- Import DDS definitions from XML or create new Definitions



DDS Blockset in action

- Import DDS definitions from XML or create new Definitions

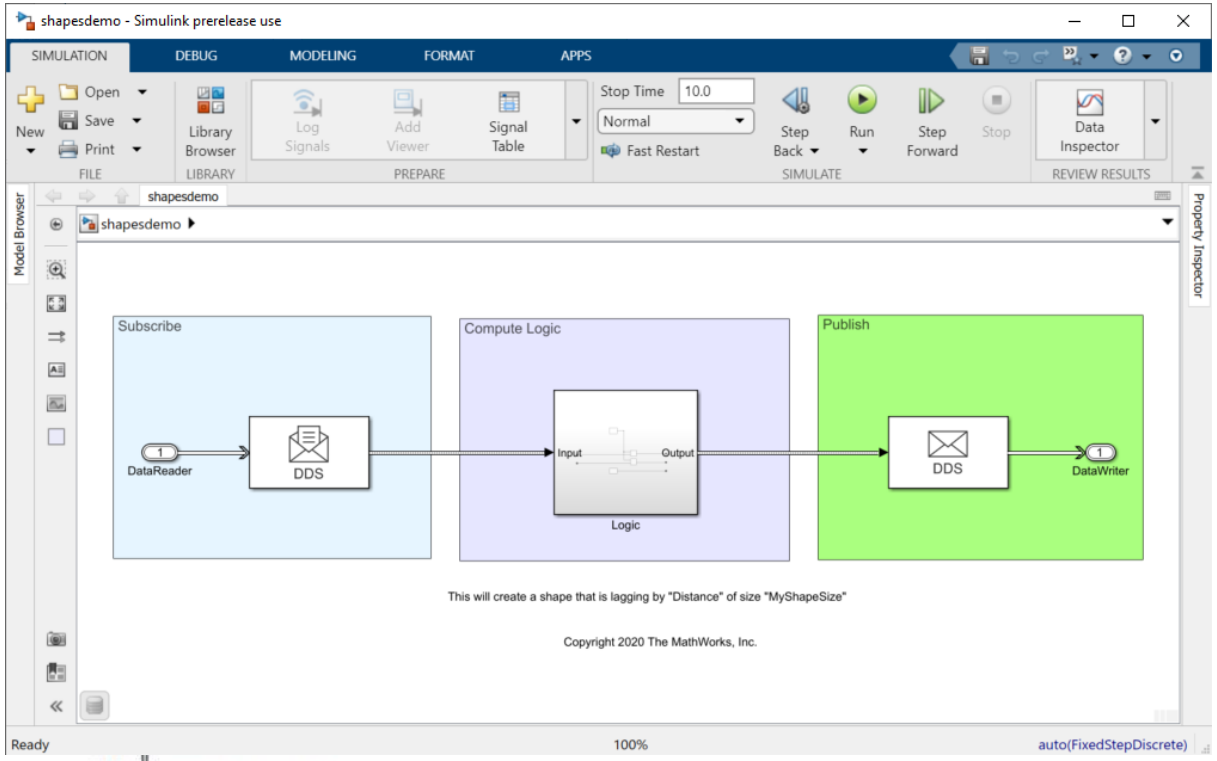
- Define/Modify DDS definitions in DDS Dictionary
  - Topic Types
  - Domains
  - QoS

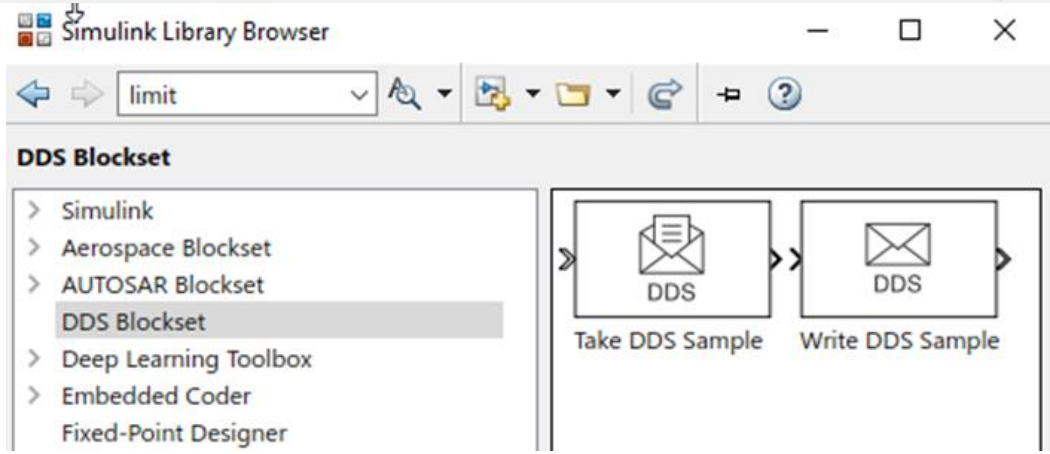


DDS Blockset in action

- Import DDS definitions from XML or create new Definitions
- Define/Modify DDS definitions in DDS Dictionary
- Model applications

Use DDS Blocks to model a Publisher or Subscriber

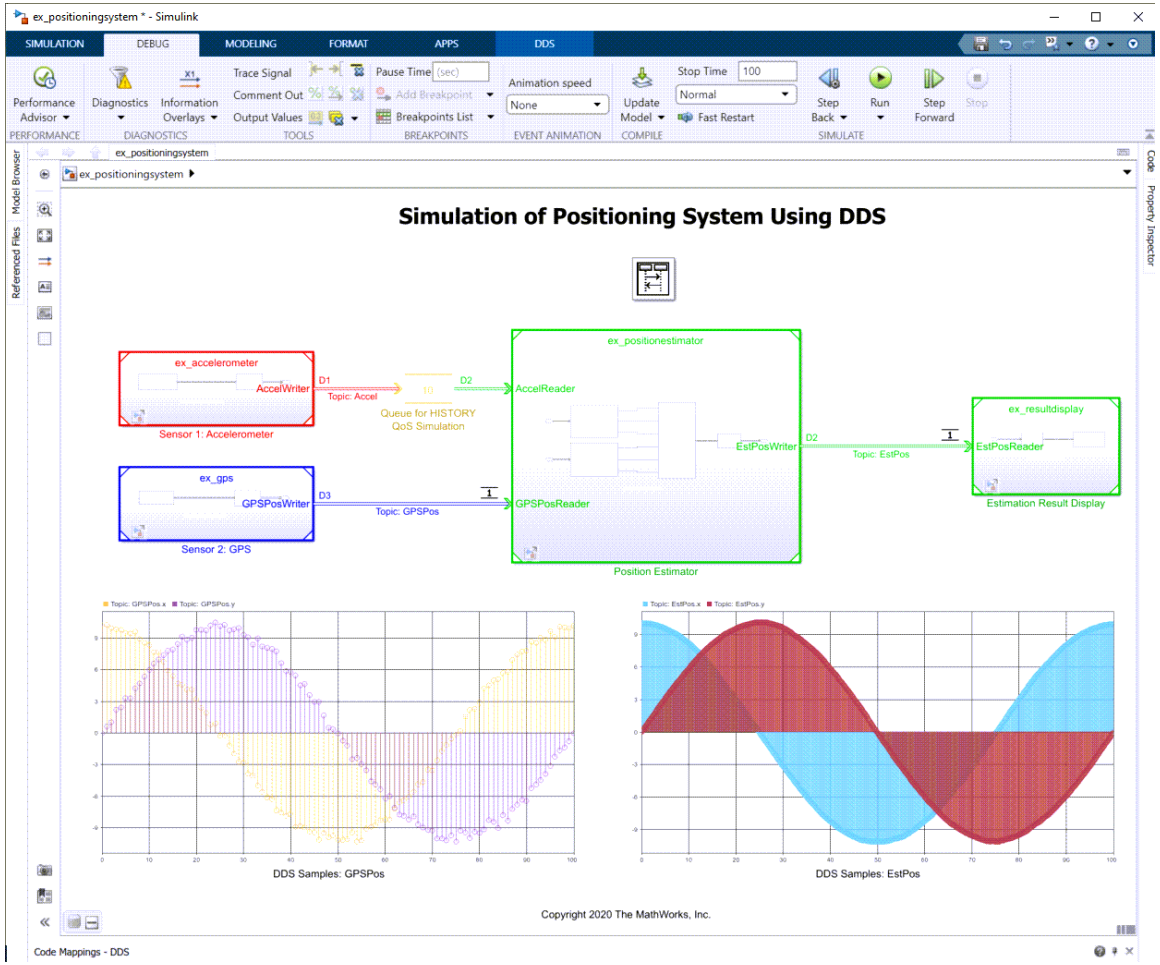




DDS Blockset in action

- Import DDS definitions from XML or create new Definitions
- Define/Modify DDS definitions in DDS Dictionary
- Model applications
- Simulate DDS models including QoS

Use Simulink to model and simulation Quality of Services (QoS) policies including **history** to verify the runtime behavior.



DDS Blockset in action

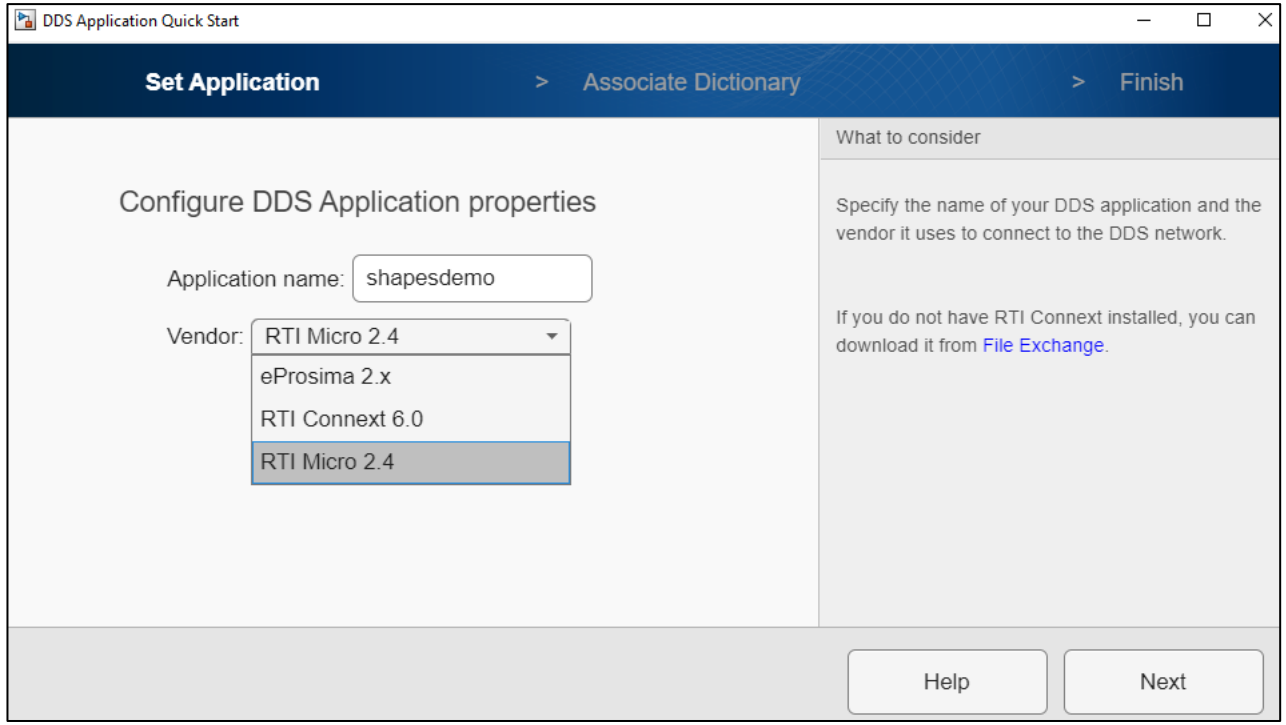
- Import DDS definitions from XML or create new Definitions
- Define/Modify DDS definitions in DDS Dictionary
- Model applications
- Simulate DDS models including QoS
- Generate DDS executables and deploy on a DDS network

With Embedded coder, generate
  - C++ production code with DDS APIs
  - XML or IDL files from Simulink models to deploy

```
bool writeWithWriter(const PosType* data, std::string participantName, std::string wr
    DDS_DataWriter* writer = getWriter(writerName, participantName);
    PosTypeDataWriter* fooWriter = PosTypeDataWriter_narrow(writer);
    if(!fooWriter) {
        return false;
    }
    const DDS_ReturnCode_t ret = PosTypeDataWriter_write((PosTypeDataWriter*)writer,
    return (ret == DDS_ReturnCode_t::DDS_RETCODE_OK);
};
bool createParticipant(std::string participantName) {
    if (participants.find(participantName) == participants.end()) {
        DDS_DomainParticipant* participant =
            DDS_DomainParticipantFactory_create_participant_from_config(
            DDS_TheParticipantFactory, participantName.c_str());
        if(!participant) {
            return false;
        }
        participants[participantName] = participant;
    }
    return true;
};
```

Model DDS application

- Import DDS definitions from XML or create new Definitions
- Define/Modify DDS definitions in DDS Dictionary
- Model application algorithms
- Simulate DDS models including QoS
- Generate DDS executables and deploy on a DDS network



Full integration with third-party DDS stacks including RTI Connext, RTI Micro and eProsima Fast DDS

Agenda

- Software-defined vehicles and new architectures (SOA)
- SOA Concepts
- MathWorks Solutions for SOA
    - Adaptive AUTOSAR
    - DDS/ROS
- Conclusions and Key Takeaways

Conclusions

Challenges

- **Automotive E/E and SW architecture are evolving**, pushed by need for advanced, complex functions
- New, **service-oriented architectures** are required to **master complexity** and enable **frequent updates**

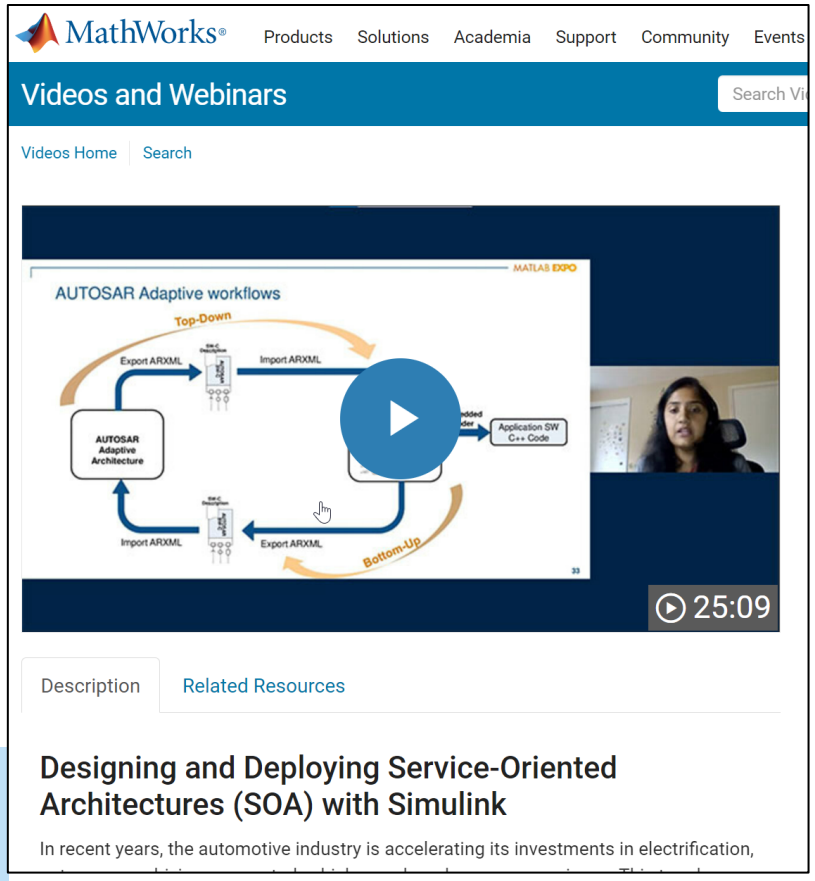
Solutions

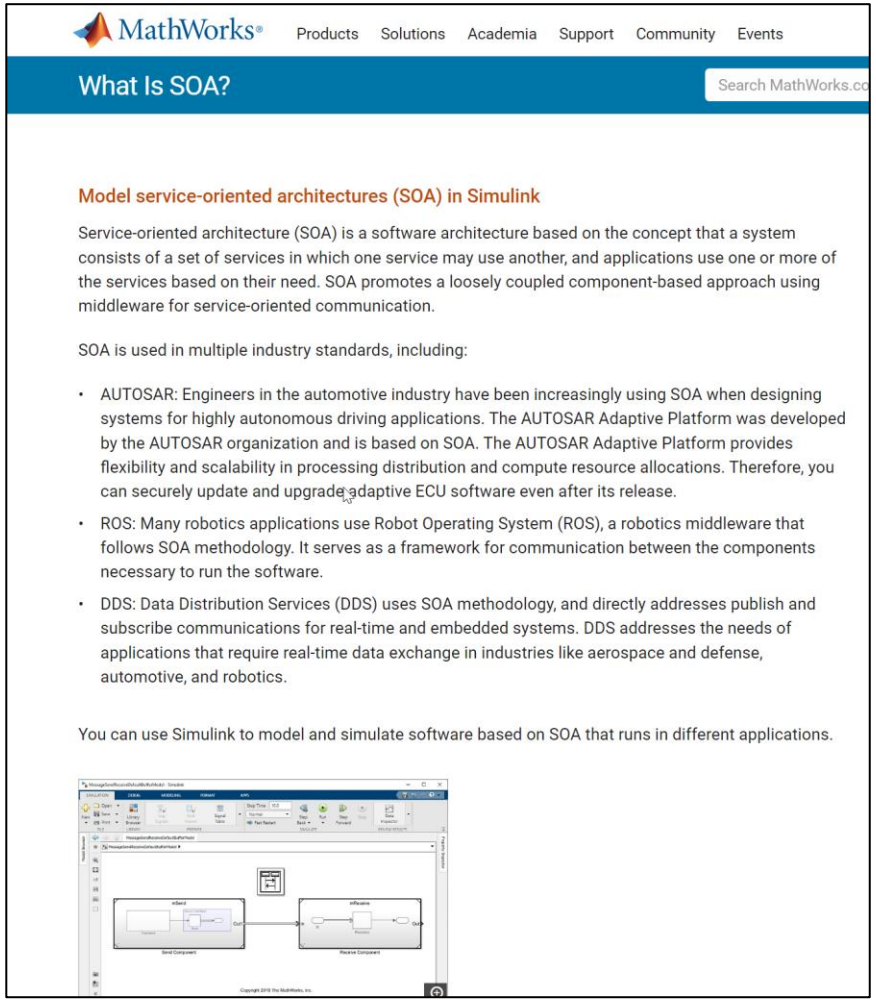
- You can **design, simulate and generate** code to deploy service-oriented applications (including AUTOSAR Adaptive and DDS) in **Simulink**
- You can **reuse your existing expertise and models** to mitigate the risk of migration to SOA applications

To find more Info:

[Service-Oriented Architectures with Simulink Ebook (mathworks.com)]

[Designing and Deploying Service-Oriented Architectures (SOA) with Simulink Video - MATLAB & Simulink (mathworks.com)]





[SOA - MATLAB & Simulink (mathworks.com)]

Reach out to us
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Nukul Sehgal nsehgal@mathworks.com

MATLAB EXPO

Thank you