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A Reference Architecture for Payload Reusable Software (RAPRS)

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Goals & Approach

♦ Goals

- Design a software architecture that can be reused across a broad range of payloads
  - →Eliminate custom, single-use-only designs
  - →Provide synergy by sharing software, developers, and tools
  - →Support new and evolving missions

♦ Approach

- Apply modern software architecture design styles
  - →Distributed hardware and software applications
- Identify current technologies and standards for implementing in highly-embedded systems
  - →Systems that have a fraction (<1%) of the processing resources of desktop computers

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Motivation

- **SNL is developing a standard data processing architecture called Joint Architecture Standard (JAS) and a new software architecture is needed to support it**
  - Focused on highly reconfigurable and distributed processing hardware
- **Developing a reusable software platform lowers cost and risk to all programs**
  - Provides high-TRL software at the beginning of a project
    - →Includes >50% of the total payload software
- **Internal Research & Development funding was available**
- **A 2009 NASA Study on Flight Software Complexity recommended, “Invest in Reference Architecture,” as a method to reduce risk to software development**

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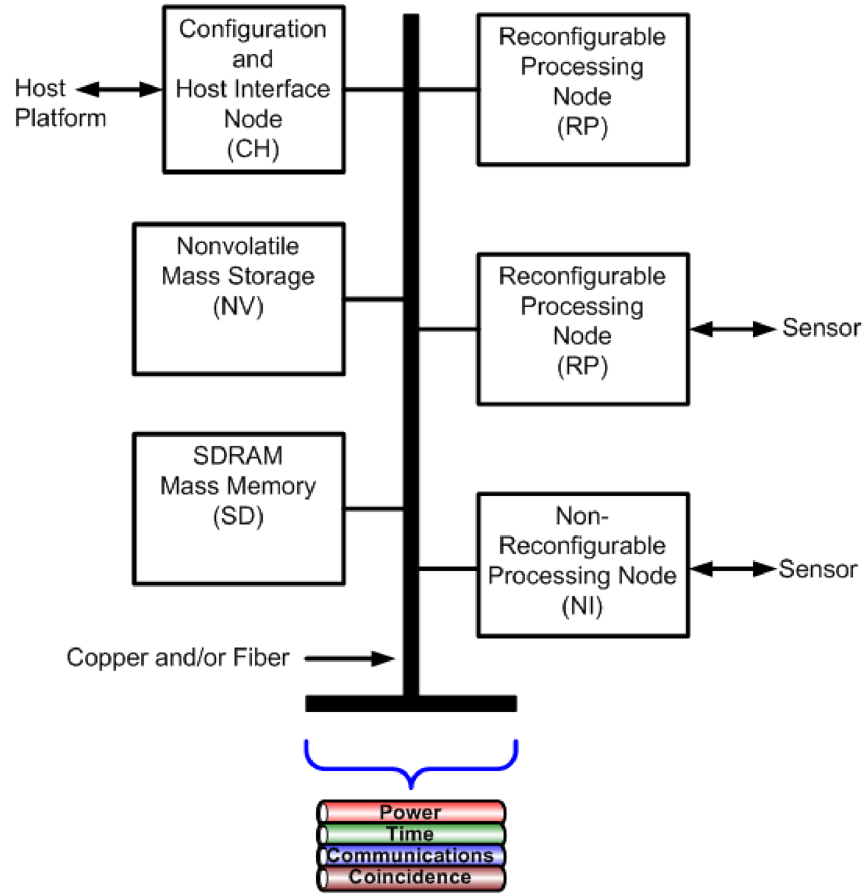
Features of JAS

- **JAS is a modular, node-based architecture that uses**
  - High-speed serial data interfaces
  - Industry standard protocols
  - Hardware and software building blocks
- **Nodes**
  - Several processing nodes
  - Mass SDRAM & non-volatile memory nodes
  - Have 2 common HW components
    - → System monitor & communications (SMAC) port
    - → Point-of-load (POL) power converters
  - Number and type are determined by system requirements
- **JAS supports**
  - Rad-hard ASIC processors
  - FPGA-based soft-core signal processors
  - HDL for custom logic designs
- **JAS offers COTS-based development and test environment for rapid system demonstration.**



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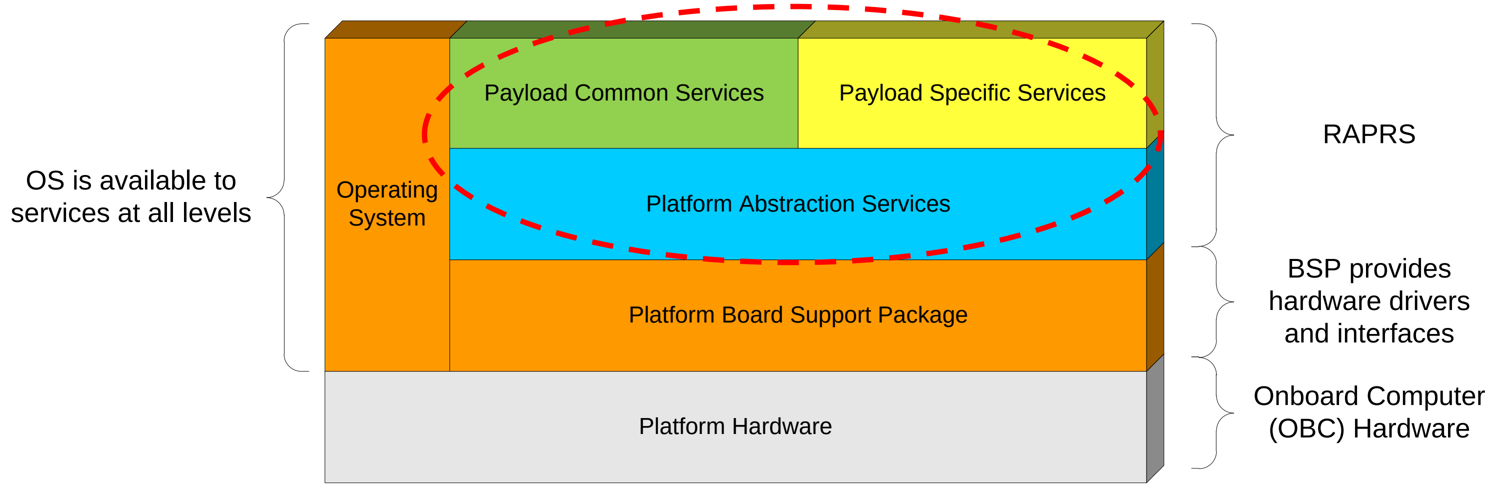
Software Requirements

- **Required**
  - Design a modular, scalable, and reusable platform
  - Support payloads with <u>significant</u> onboard processing needs
    - → Command and Data Handling (C&DH)
      - – Support tens of thousands of command and telemetry parameters
    - → Complex instrument control
    - → Sensor data processing from kbits/s to Mbits/s
    - → Real-time and intermittent ground system interaction
  - Support payloads in different orbits (LEO to GEO)
  - Support new and legacy ground systems
- **Desired**
  - Dynamically update software without system interruption
    - → Support new missions through software reconfiguration

Minimum Hardware Configuration

- **CPU – Hard or soft-core processors**
  - 32-bit processor with hardware floating point unit, 75+ MHz
    - →LEON3 SPARC, PPC-603, PPC-750
- **RAM – Depends on application requirements**
  - 16MBytes to 64MBytes
- **NVRAM – Store hardware and software applications**
  - 1Mbyte to 64Mbytes
- **PROM – Boot loader and applications**
  - 128Kbytes to 256Kbytes
- **Network – Depends on mission requirements**
  - Nominally >10Mbps for C&DH

Layered Architecture



- Platform Abstraction Services (PAS) provide a standardized and abstracted communication interface to all payload hardware
- Payload Common Services (PCS) provide many of the functions necessary for controlling a payload and communicating with the ground system
- Payload Specific Services (PSS) are the functions that are unique for each payload

A layered architecture allows RAPRS to be reusable on different hardware

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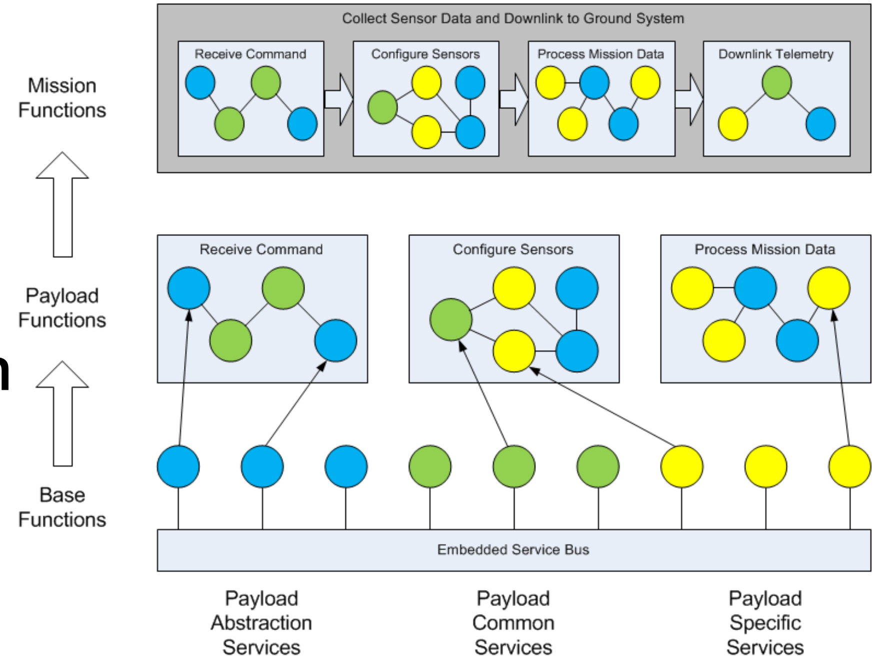
Event-Driven Service Oriented Architecture

- **Combines modular services of SOA with an event-driven architecture to create a "reactive system"**
- **Simplifies interfaces between services**
  - Services send and receive "events" through a publish/subscribe interface
  - Events are routed based on "topics" to subscribing services



- **An Embedded Service Bus (ESB) allows services to communicate in a distributed heterogeneous computing environment**

Even-Driven SOA provides the modular and scalable framework for RAPRS

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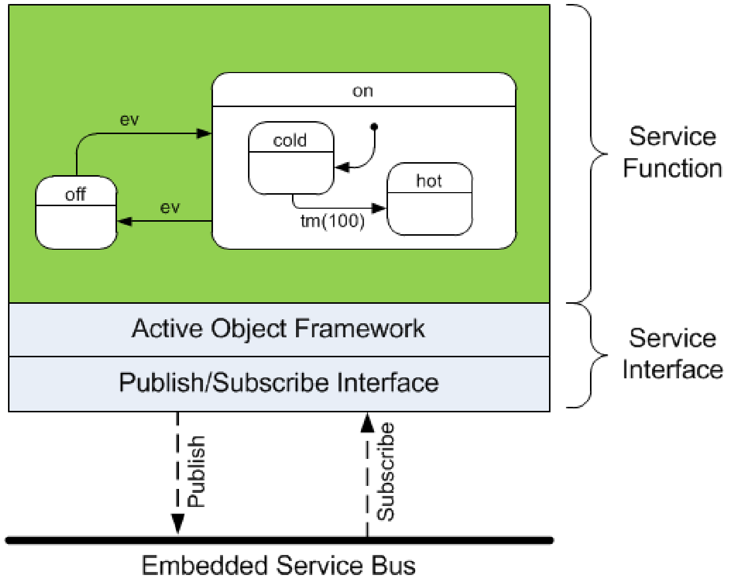
A Software Service

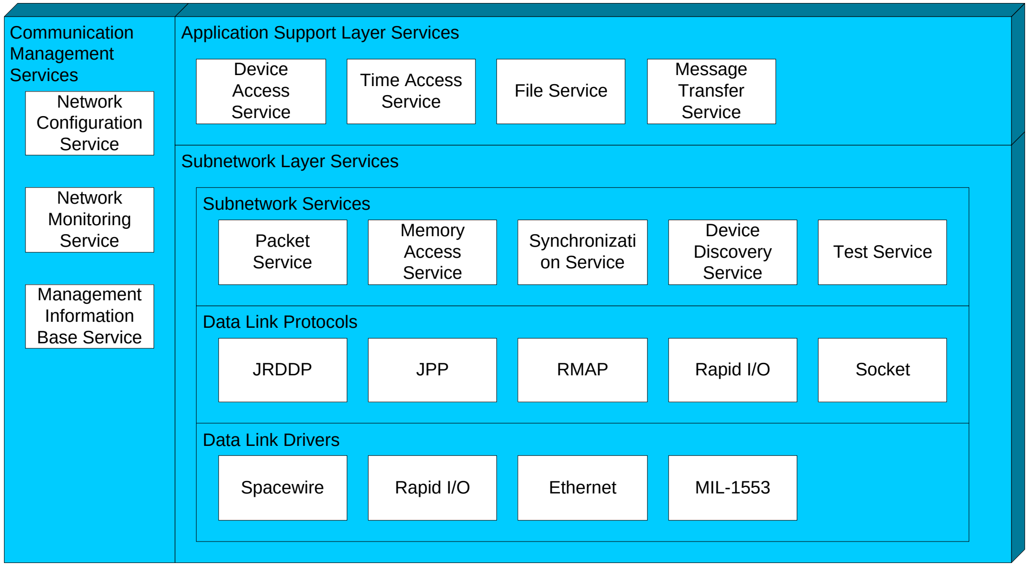
- **Services are implemented in terms of a standard framework**
  - Service Function
  - Service Interface



- **The framework is implemented with:**
  - An Active Object (AO) Framework provides the event-driven execution framework
  - Data Distribution Service (DDS) provides the ESB that allows services to be seamlessly distributed across one or more processing elements

Platform Abstraction Services

- Services that provide standard interfaces for accessing payload hardware
- Access payload hardware regardless of location or communication interface
  - Hides the details from upper-layer services



- Based on CCSDS-SOIS
  - Services APIs are implemented as events
- Data links are based on Spacewire and Serial Rapid I/O
- Subnetwork Layer Services can be implemented in hardware (VHDL) or software

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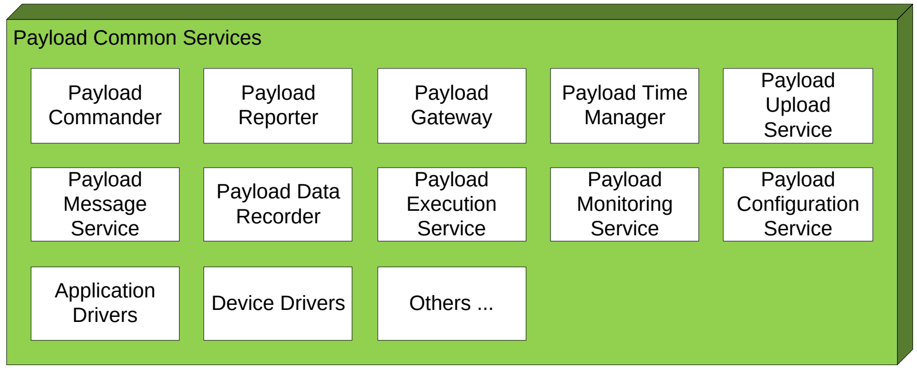
Payload Common Services



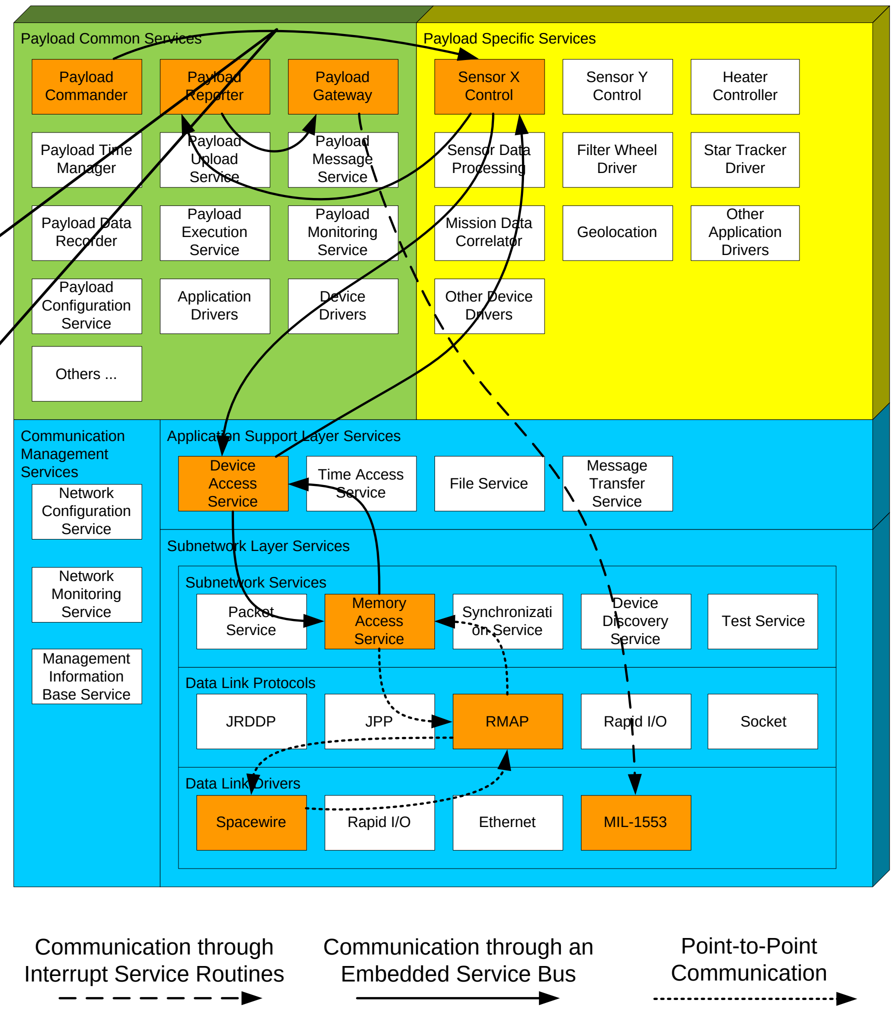
- Translate between F/G protocol and payload events
- Execute commands
- Collect and report SOH data
- Manage and distribute time
- Upload and store HW/SW apps.
- Collect and report messages
- Read/Write to a data recorder
- Deploy HW/SW apps.
- Monitor payload HW/SW state
- Distribute configuration data
- Templates for Application and Device Drivers

Programs can pick and choose the services they need

Aggregation of Services

- Services subscribe to event topics
- Data within the event is used to “filter” the events to the subscribers

```
Event Topic          Configure Sensor
Event Topic ID       0x00000001
Event Data
      Source Application ID            32-bit Integer
      Destination Application ID       32-bit Integer
      Transaction ID                   32-bit Integer
      Command ID                       32-bit Integer
      Number of Command Parameters     32-bit Integer
      Length in Bytes of Parameters    32-bit Integer
      Parameter Data                   Byte Sequence
            Sensor Name
            Collection Type
            Collection Seconds
```



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Embedded Scripting Languages

- **An embedded scripting language allows you to separate program-specific functions from a service**
- **How it works**
  - Develop the service to provide program-independent functions
  - Implement program-specific functions in the scripting language
  - Events passed into the service include references to scripts to be executed
  - Scripts are executed through a function call to the scripting language interpreter
- **Examples**
  - Commanding Service runs scripts to perform “complex” commands
  - Gateway Service executes scripts to translate between events and the F/G communication protocol
- **Advantages**
  - Services are more reusable
  - Scripts can change without having to recompile the software
- **Disadvantages**
  - Performance
  - Capability is limited by the features of the scripting language
- **Lua can extend programs written C, C++, Ada, Java and others**

Payload Configuration and Interface

```
<object>
  <name>Red Hill</name>
  <position>
    <lat>-33.69</lat>
    <lon>18.83</lon>
  </position>
</object>
```

```
object* obj = ...; // Parse XML.
const char* name = obj->name ();
position& pos = obj->position ();
float lat = pos.lat ();
float lon = pos.lon ();

delete obj;
```

- **The payload is defined in terms of XML data files**
  - CCSDS-XTCE is used as the schema
- **An XML Data Binding compiler converts XML elements to software objects**
  - Creates the classes as well as parsing and serialization code
  - Code Synthesis XSD/e XML Schema to C++ Compiler
- **Flight software uses the software objects to manage the configuration and state of the payload**
- **Ground software uses the software objects to send commands and process telemetry data**

Status

- **Current R&D efforts have focused on proving the JAS hardware**
  - Demonstrated the layered architecture and abstraction
  - Implemented the event-driven framework using Rhapsody OXF
    - → Used point-point routing of events between services
  - Implemented many of the Platform Abstraction Services
    - → Spacewire network configuration and monitoring
    - → RMAP and CCSDS packet protocols
    - → Time distribution
    - → Remote file system access
    - → Loading bit-files applications in FPGAs
- **Testing with RTEMS and Linux running on LEON3**
- **Porting Opensplice DDS to RTEMS to demonstrate an ESB**
- **Gather resource and performance data**

Future Plans

- **New programs are using JAS/RAPRS in their plans**
- **Continue to develop a library of new services**
  - Complete the implementation of abstraction services
  - Start adding elements of the common services as needed
  - Create a standard service framework for developing new services
- **When other programs adopt this design approach, the services library will grow so others can take advantage of existing services**

References

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