MO Services, SOIS and SAVOIR Harmonisation: Project Status

Peter Mendham, Bright Ascension
Simon Reid, RHEA System
Andreas Wortmann, OHB System

Agenda

- Introduction to the MOSS activity and its goals
- The MOSS approach to consolidation and consolidation aims
- Technology review
- Consolidating the user needs and requirements
- The consolidated architecture
- Looking ahead to the harmonised architecture
- Technology issues arising during consolidation and recommendations
- The proof-of-concept prototype
- Next steps
- Summary and conclusions

The MOSS activity

Activity objectives

- Analyse three technologies with a view to using them to create a **single harmonised architecture**
  - CCSDS Mission Operations Services (MO)
  - SAVOIR Onboard Software Reference Architecture (OSRA)
  - CCSDS Spacecraft Onboard Interface Services (SOIS)
- The harmonisation must be driven by user needs and requirements
  - The original user needs and high-level requirements for the technologies
  - If these are not currently documented they must be elicited
- A suitable harmonised architecture should be proposed
  - This must take into account to expected migration path
  - Intermediate architectures may be necessary
  - The relationship with PUS(-C) should be captured
- Key aspects of the resulting architecture should be prototyped

Approach

- Balance of bottom-up and top-down activity
- Technology-driven – *bottom-up*
  - Technologies of interest are clearly identified in the scope of work
  - Technologies are selected due to their potentially strategic importance
  - Stage of development of the technologies likely permits influence over direction
- Requirements-driven – *top-down*
  - Starting point for consolidation is user needs and requirements
  - Consistent approach taken to requirements gathering across technologies
  - Requirements are consolidated before technologies
- Breadth rather than depth
  - Many consolidation issues are to be found at architectural level
  - Design and prototyping attempts to cover the full breadth of the architecture
  - Prototype will not go into full detail in all aspects

Feedback and recommendations

- Breadth of MOSS activity allows checking for alignment
  - Flight and ground differences in conceptual approach
  - Alignment between MO and the OSRA
  - Further examination of alignment between MO and SOIS
- Feedback to relevant working groups
  - SAVOIR and CCSDS (MOIMS and SOIS)
- Recommendations of changes to permit better alignment
  - Essential and advisable changes
  - Short-term and long-term changes
- Recommended adoption approach
  - Especially for the adoption of MO onboard

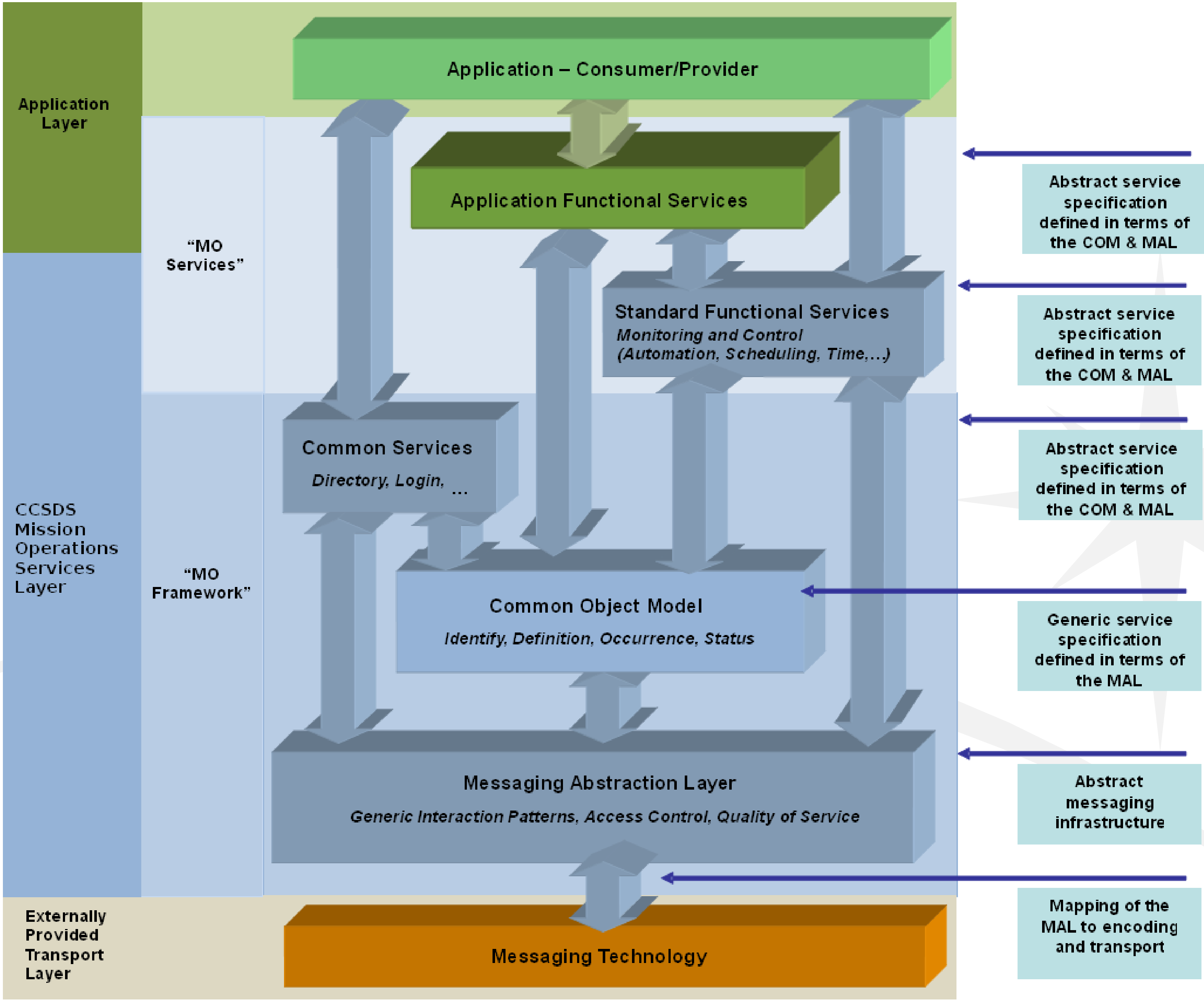
Technology review

MO: vision

- Service infrastructure for large-scale distributed system
  - Spans local area, wide are and space-ground networks
- Layered approach
  - Well-defined, rich, semantic services
  - Service interactions
  - Communications protocols
- Key drivers and motivation:
  - Greater cooperation, e.g. inter-agency, hosted payloads etc.
  - More efficient operations with greater automation
  - Technology-independence and long-term maintainability
  - Modular systems and plug-in components
  - Taking a space system-centric approach through development and operations

MO: context and concepts

- Key terminology
  - Mission Operations (MO) is used to refer to the complete technology
  - MO Framework is the underlying service-oriented framework
  - MO Services are the services which utilise the framework to interact
- MO Framework
  - Common services (e.g. directory, login etc.)
  - Common Object Model (COM) – meta-model, service patterns and archiving
  - Message Abstraction Layer (MAL) – abstract messaging, service meta-model
  - Concrete communications protocol binding
- MO Services
  - Monitor and Control (M&C) Services, in draft
  - Automation, Scheduling, Time, Remote Buffer Management, File Management and Broker Services all to be defined
- Extended by application services


Application Layer
Application – Consumer/Provider
Application Functional Services
"MO Services"
Standard Functional Services
Monitoring and Control
(Automation, Scheduling, Time,...)
CCSDS Mission Operations Services Layer
Common Services
Directory, Login, ...
"MO Framework"
Common Object Model
Identify, Definition, Occurrence, Status
Messaging Abstraction Layer
Generic Interaction Patterns, Access Control, Quality of Service
Externally Provided Transport Layer
Messaging Technology
Abstract service specification defined in terms of the COM & MAL
Abstract service specification defined in terms of the COM & MAL
Abstract service specification defined in terms of the COM & MAL
Generic service specification defined in terms of the MAL
Abstract messaging infrastructure
Mapping of the MAL to encoding and transport

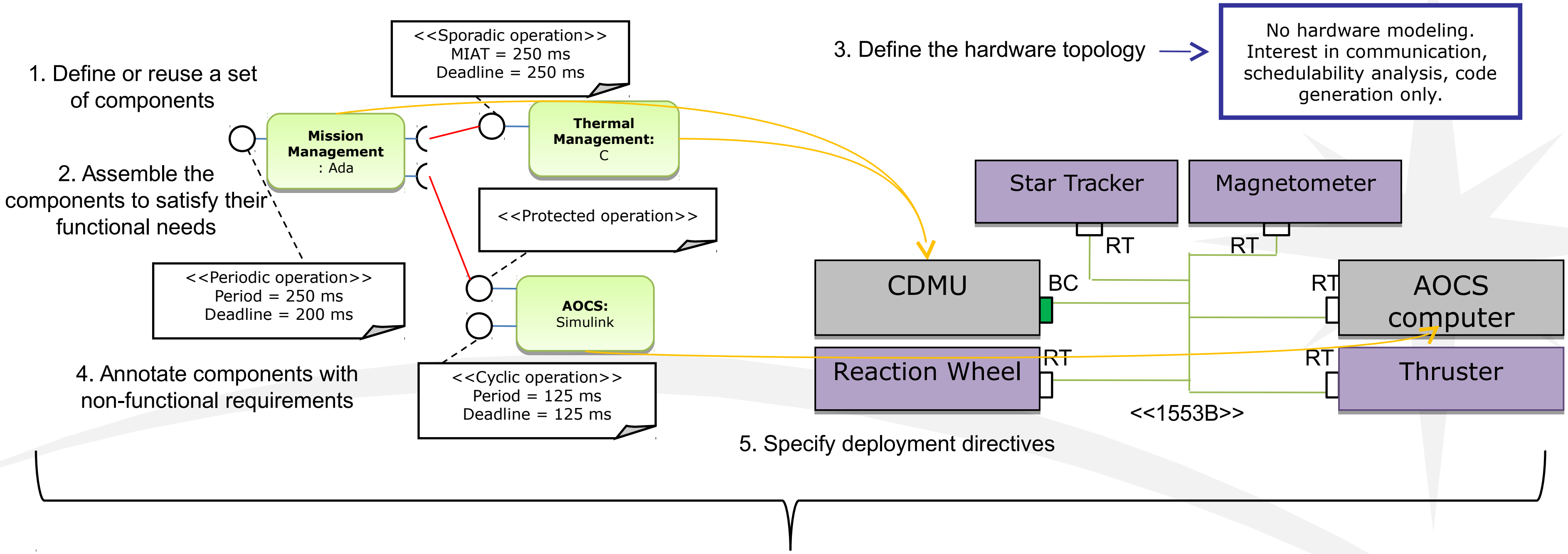
MO: use cases

- Short term focuses on practical application of MO framework
  - Makes use of communications framework and service interactions
- Long term focuses on semantics
  - Makes use of semantic services for more efficient operations and development
- Short-term use cases
  - Generic M&C for payload operations
  - Inter-agency hosted payloads
  - Automated payload functions
- Long-term use cases
  - Semantic payload operations
  - Automation services
  - System-level design with MO

OSRA: vision

- Address the pressures on onboard software
  - Greater functionality
  - Greater value for money
  - Schedule pressure to have software available sooner but flexible until later
- Work within the environment for onboard software in Europe
  - Assurance requirements
  - Commercial and geopolitical constraints
- Utilises
  - Model-based software engineering
  - Component-based technology
- Encourages software reuse and the emergence of product lines in software

OSRA: development process

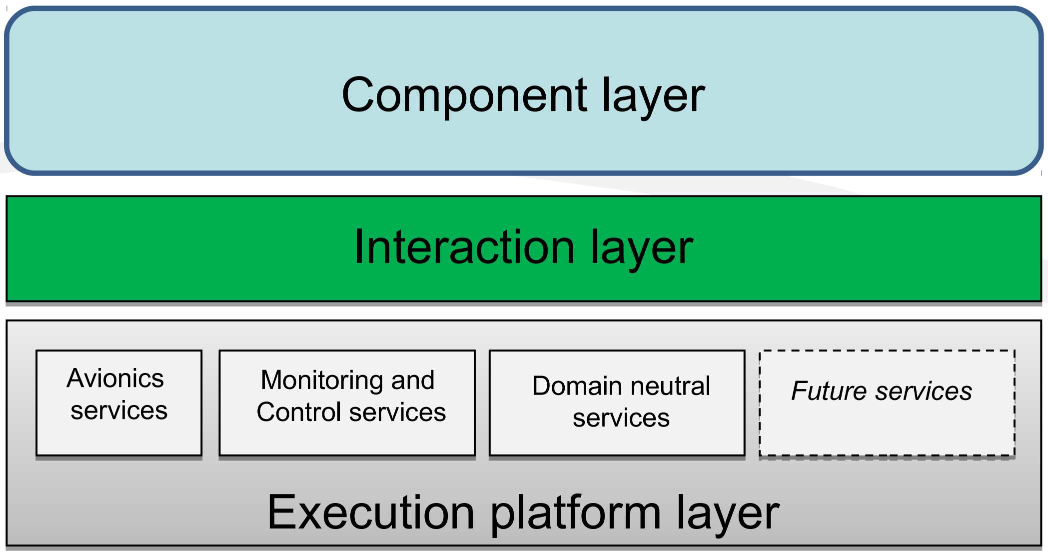


6. Automatically analyse the software **model** to ascertain that the **whole set** of non-functional properties can be fulfilled

Taken from the OSRA Training Material

OSRA: run-time architecture

- OSRA components sit inside their containers and utilised connectors
  - Both of these rely on functions offered by the underlying Execution Platform
- Containers and connectors are **tool-generated at deployment time**
  - They form the I**nteraction Layer**



OSRA: use cases

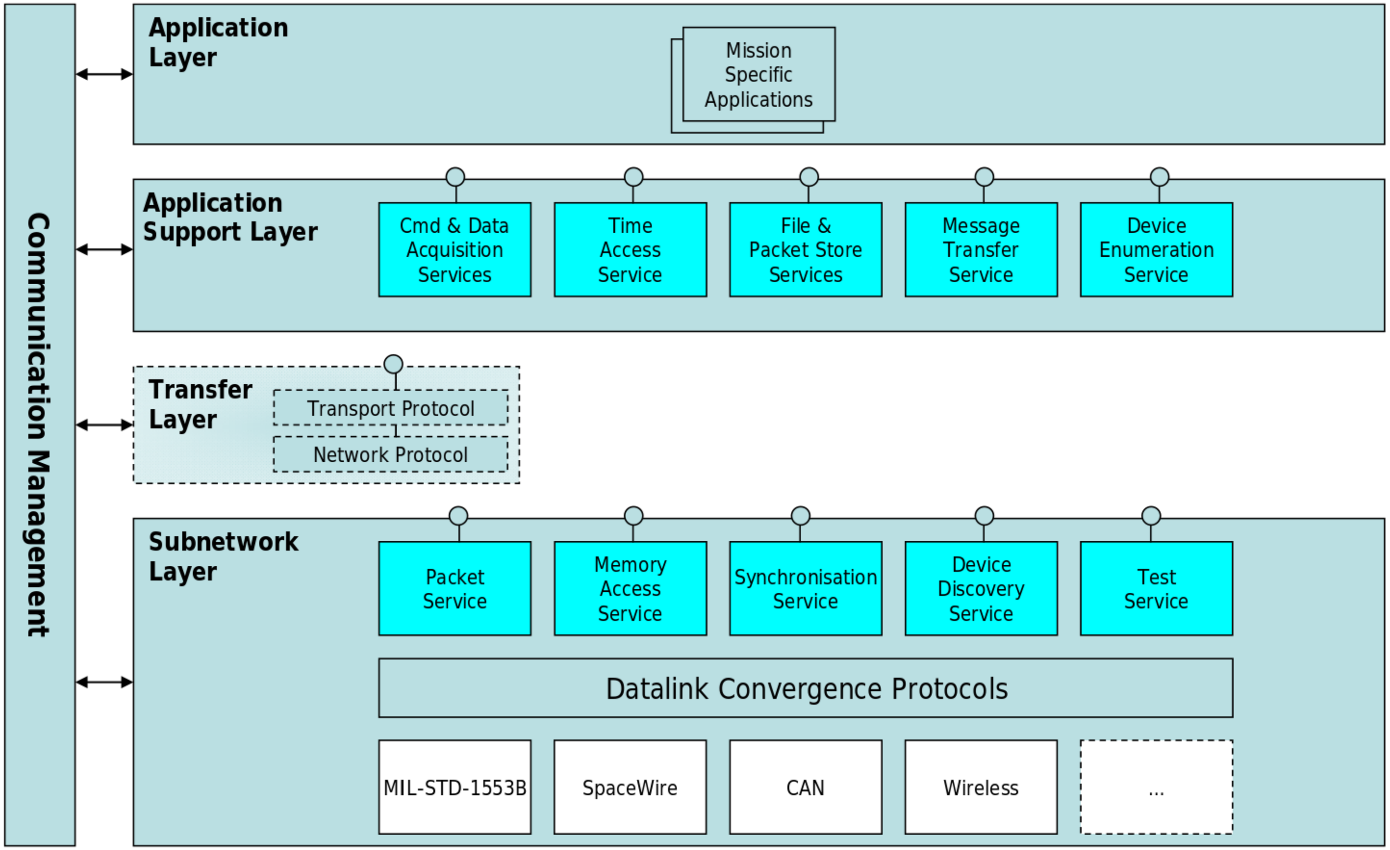
- Short term focuses on improving the development workflow
  - Software reuse within organisations, automation of simple analyses
- Long term focuses on extending the role of the OSRA
  - Software reuse across organisations and the introduction or products
  - More complex analyses and support to assurance
- Short-term use case
  - Developing reliable software in an uncertain environment
- Long-term use case
  - Rapid development of assured software

SOIS: vision

- Improve the design and development process of onboard data systems
  - Defining generic services for interactions between flight software and hardware
  - Increase potential for interoperability and reuse
- Potential benefits include
  - Reduced development cost and risk
  - Shorter development times
  - Easier integration
  - Encouraging the emergence of off-the-shelf equipment
- Utilises a reference communications architecture
  - Spanning hardware and software
- Includes an approach to “plug-and-play”
  - Spans design-/development-time approaches as well as run-time approaches

SOIS reference architecture

- Specified in terms of services, each defined by their interface
- Service implementations are not specified



SOIS: use cases

- Short term focuses on encouraging reuse through standard interfaces
    - Such as avionics hardware, software or EGSE reuse
- Long term focuses on improving development workflow
    - Introduction of plug-and-play technologies
- Short-term use case
    - Reuse of avionics hardware across missions
- Long-term use case
    - Rapid integration of avionics using standard services and electronic datasheets

Technology aims: common aims

- Common aims:
  - Reduced development costs
  - Increased development adaptability
  - Decreased risk
- Common Architectural characteristics:
  - Modularity to enable reuse
  - Encapsulation and abstraction to control complexity
  - Semantically-structured interfaces
  - Standardised interfaces
- The different foci of the technologies also creates some differences

Technology aims: differences (1)

- Operations is the main focus for MO
  - Operations is run-time behaviour
  - MO also cares about the way software is constructed
    - Need to allow cross-agency operations
- Development is the main focus for SOIS and the OSRA
  - This is design-time behaviour
  - For example: 13 User Needs presented for the OSRA
    - 12 design-time User Needs
    - 1 run-time User Need
  - Abstraction and layering are seen as useful at design time and harmful at run time
  - Certainly in the OSRA, less so in SOIS, tooling is used to *remove* design-time layering and abstraction at run-time
- This is a crucial difference between the technologies

Technology aims: differences (2)

- A key point worth emphasising is difference of scope
- Scope of SOIS
  - Single process space
  - Onboard a spacecraft
- Scope of the OSRA
  - Multiple process spaces (if necessary)
  - Onboard a spacecraft
- Scope of MO
  - Multiple process spaces
  - Across the complete space-ground system
    - Or system-of-systems
- What defines a system as “onboard”?
  - Embedded, real-time, resource-constrained, high-dependability
  - Subject to monitoring and control

Consolidated user needs/requirements

- Bring together superset of user needs and high-level requirements
- Combine user needs/requirements where they align
- Resulting vision addresses development-time and operational concerns

- Introduce semantically sound, generic services
- Support improvements to operability, observability and automation
- Promote improvements to development without sacrificing assurance
- Encourage the complete space system to treated as a whole for
  - Development
  - Operations

Consolidated architecture

Consolidation aim

- The aim of consolidation is to

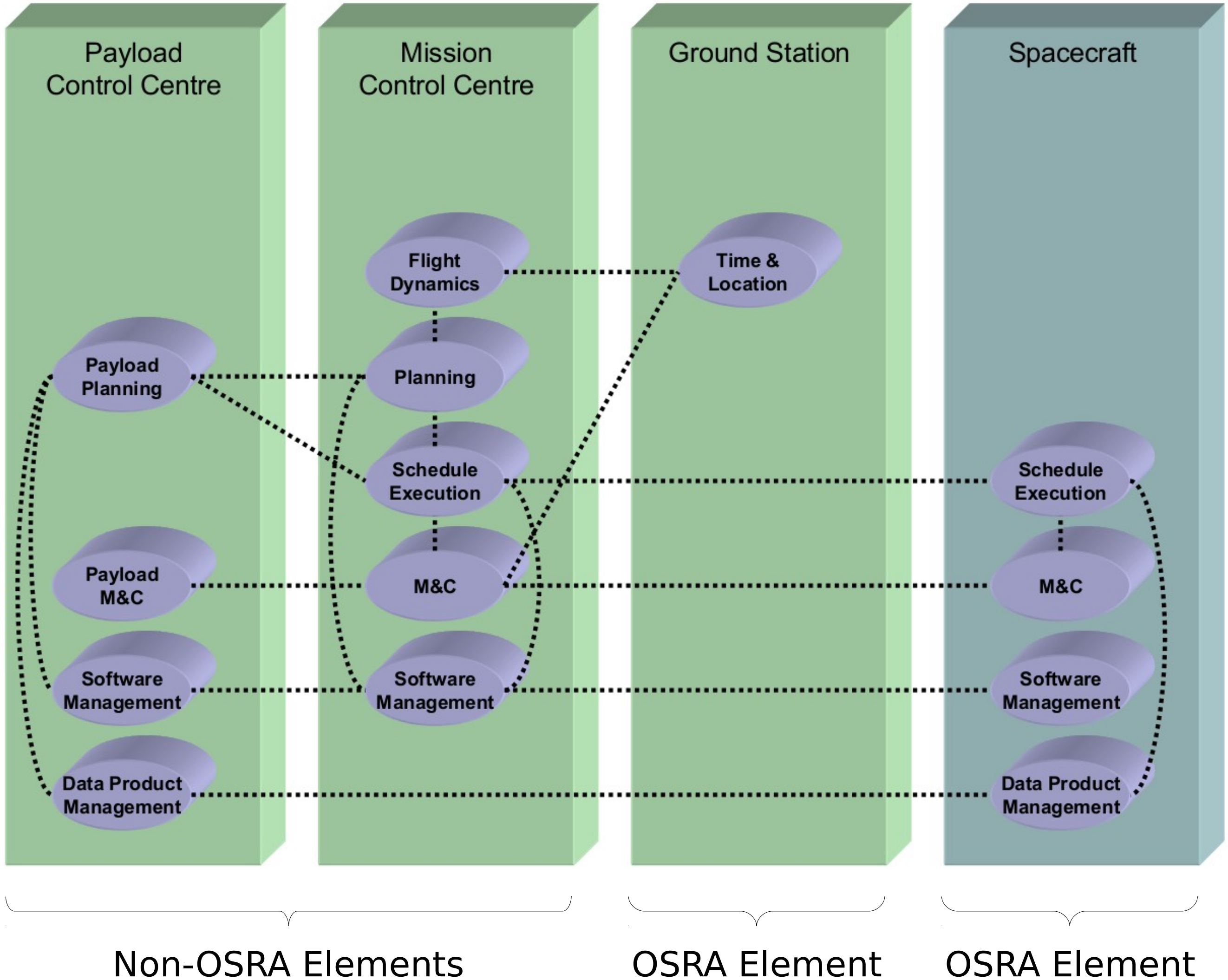
  allow the combination of MO, SOIS and the OSRA such that the benefits of each individual technology are maintained

- The benefits of each technology should be captured in their
  - User Needs
  - High-level Requirements
- Need to take into account
  - Development-time and run-time needs
  - Differences in scope
  - Should not force the use of a particular technology
- Balances top-down and bottom-up approaches
  - Technology-focussed but aims to meet consolidate high-level requirements

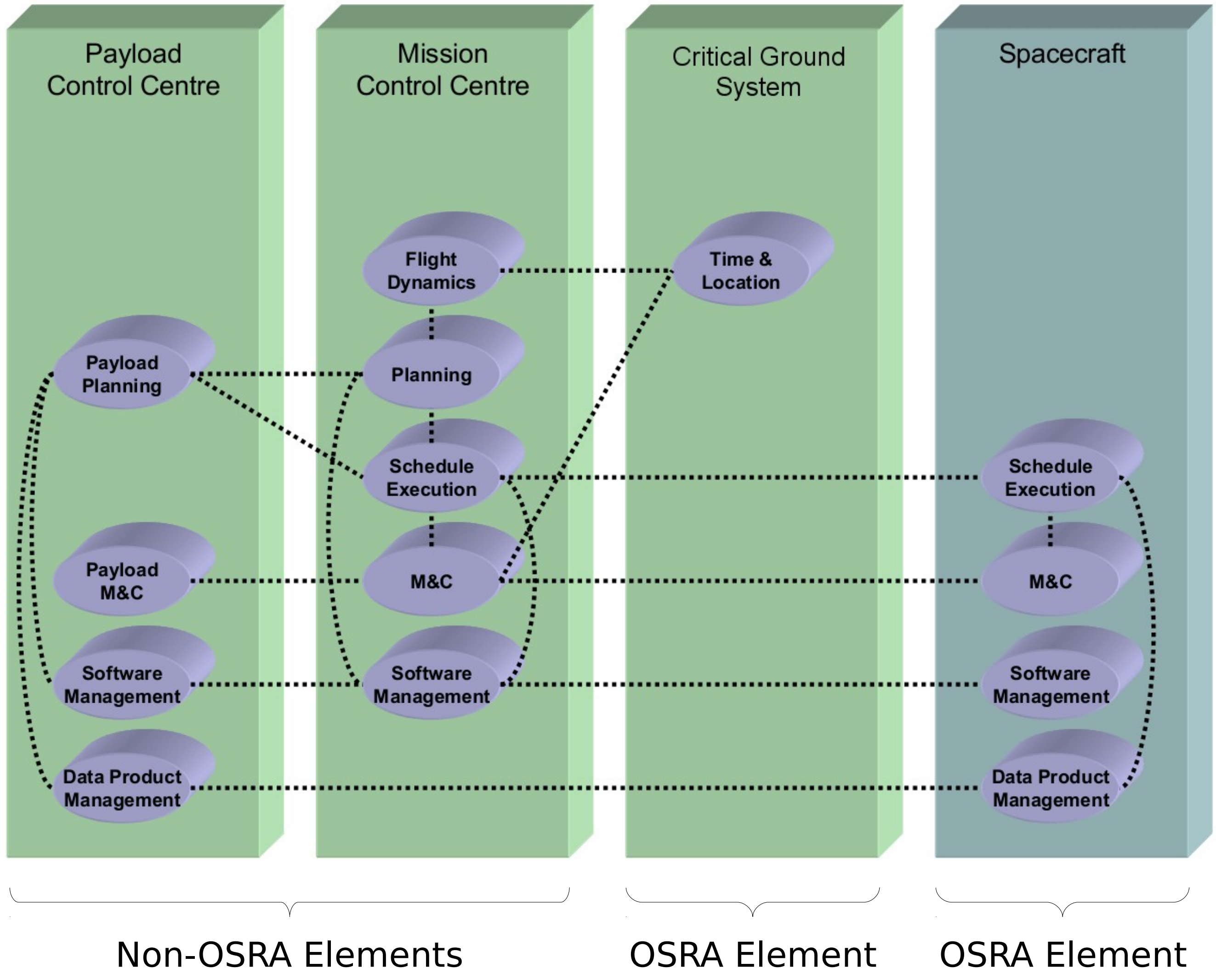
Consolidation approach

- Allow the application of the OSRA and SOIS within an MO architecture
- Identify specific regions or *elements* of an MO system
  - These are developed using the OSRA
  - Also allow use of SOIS
- No need to apply the OSRA/SOIS to other elements
- For example
  - MO system spanning MCC, PCC, Ground station(s), Spacecraft
  - Spacecraft could be developed using the OSRA (and therefore SOIS)
  - Remaining systems largely unaffected at development time
  - At run time, functions of OSRA/SOIS exposed in a uniform way via MO
  - The OSRA approach could be applied to other embedded, real-time, resource-constrained, high-dependability systems subject to monitoring and control
    - e.g. Payload performance monitoring

OSRA elements with an MO architecture



OSRA elements with an MO architecture

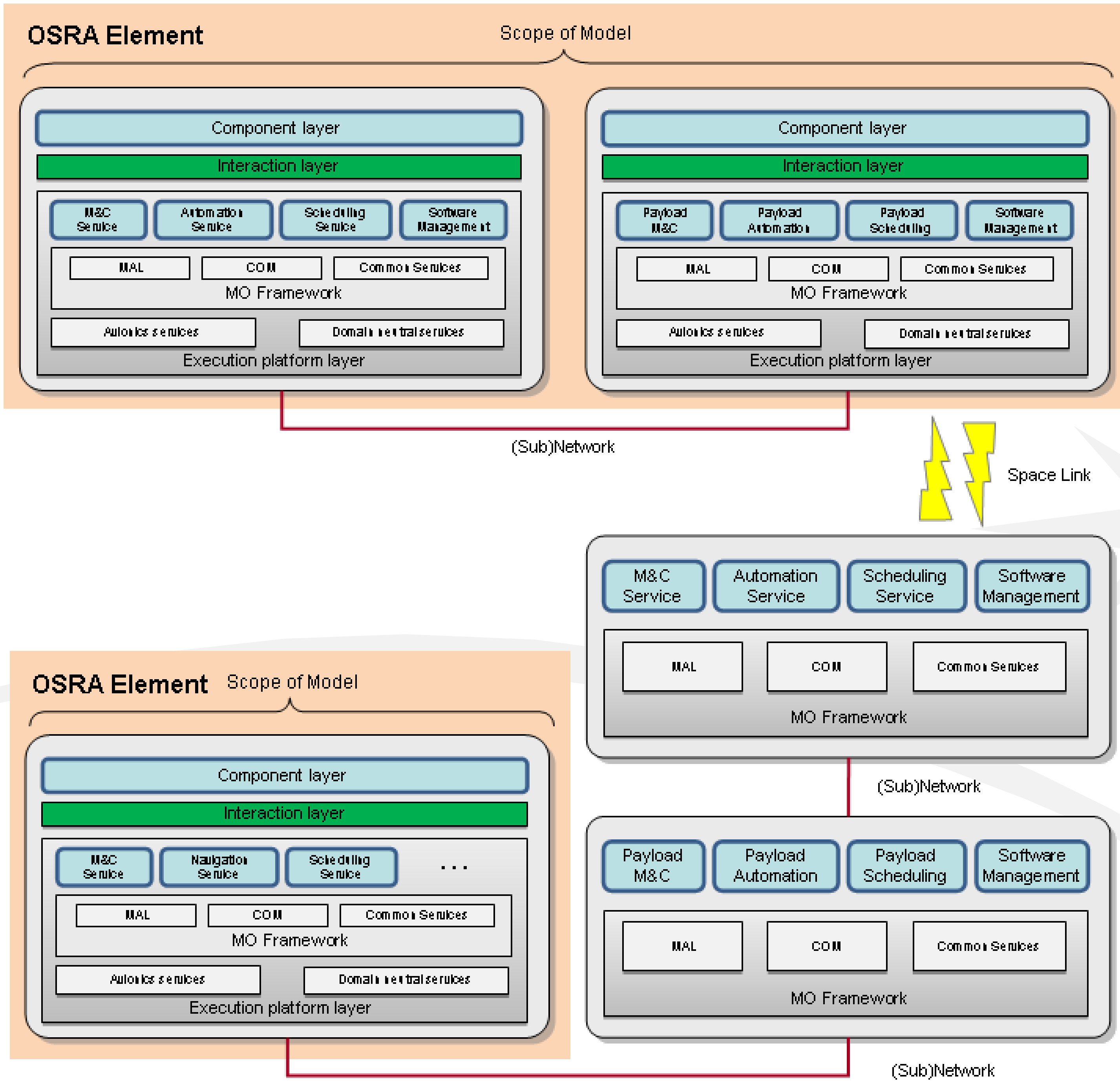


The consolidation vision

- Design time
  - Adopt a global, model-based, service-oriented architecture
  - Allow the exchange of design information
    - Corresponds to a single, shared model of services and their interface
    - Extend the MO service to support the necessary information
  - Permit component-based development within this architecture
  - Allow support for quality assurance of high-dependability elements
  - Adopt standard service interfaces to promote portability
- Run time
  - Maintain the service-oriented architecture at run-time
  - Ensure all system elements utilise consistent external interfaces
  - Adopt communications standards to allow interoperability

Consolidated architecture

- MO is used as the mechanism for integrating the system
  - The common model is MO service specifications and the COM
- The capabilities of OSRA components are exposed through MO services
  - Custom services to match the component interfaces
- MO is used for OSRA components to communicate if they are on different computing nodes
- MO is used within the OSRA Execution Platform
- SOIS is used to provide interfacing and platform I/O services
  - The capabilities of SOIS devices are exposed through MO services
  - Custom services to match the device interface
  - Other SOIS services are mapped to MO services
- Nodes which do not require OSRA/SOIS are unaffected
  - Just use MO as envisaged by MO
- Staged migration from PUS is possible (and valuable)


OSRA Element
Scope of Model
Component layer
Interaction layer
M&C Service
Automation Service
Scheduling Service
Software Management
MAL
COM
Common Services
MO Framework
Avionics services
Domain neutral services
Execution platform layer
Component layer
Interaction layer
Payload M&C
Payload Automation
Payload Scheduling
Software Management
MAL
COM
Common Services
MO Framework
Avionics services
Domain neutral services
Execution platform layer
(Sub)Network
Space Link
M&C Service
Automation Service
Scheduling Service
Software Management
MAL
COM
Common Services
MO Framework
(Sub)Network
OSRA Element
Scope of Model
Component layer
Interaction layer
M&C Service
Navigation Service
Scheduling Service
...
MAL
COM
Common Services
MO Framework
Avionics services
Domain neutral services
Execution platform layer
Payload M&C
Payload Automation
Payload Scheduling
Software Management
MAL
COM
Common Services
MO Framework
(Sub)Network

Transition to the consolidated architecture

- Consolidated architecture can be applied **without utilising MO on the space-ground link**
- Most important aspects of the consolidated architecture
  - Model exchange between system elements
  - Raised semantic level of operations
- In a system with a single spacecraft which is treated as a single system
  - MO is not necessary onboard to enable use of MO on ground
  - High semantic level of OBSW can be introduced through components
  - Components can appear as MO services to ground systems
  - MO to TM/TC (e.g. PUS) bridge used to interact with spacecraft
- Adds significant value to space-ground system without requiring significant changes to onboard Execution Platform
- Valuable **migration path** to use of all of the technologies in practice

Harmonised architecture

Beyond the consolidated architecture

- Consolidated architecture aims to meet consolidated high-level requirements
  - But balances these against technology “requirements”
  - Aims to keep current technologies largely intact
  - Short-term approach
- Harmonised architecture is entirely focussed on meeting the consolidated high-level requirements
  - Aims to learn from technologies
  - Does not aim to reuse technologies as-is
  - Suggestions a longer-term migration path
- Adoption of the harmonised architecture offers the greatest benefits
  - Also solves a number of existing problems, both technical and industrial
  - However, a number of significant problems must be solved
- Harmonised architecture is the long-term approach

Harmonised architecture vision

- Create a single conceptual architecture across the complete system
- One component meta-model for all elements
  - Combine component- and service-oriented approaches
  - Accommodate static and dynamic binding
  - Based on the OSRA component model with the addition of services
- One model to represent the complete system
  - The same model across development and run time
  - Model is dynamic: evolves during development and operations
  - Model can be queried at design and run time
- Key aspects of deployment captured in the model
  - Logical deployment (as SSM) c.f. MO domains
  - Physical deployment c.f. MO network zones

- Much more powerful approach than consolidated architecture

Moving to the Harmonised Architecture

- Requires a new concept of a component → a new meta-model
  - To accommodate OSRA component meta-model + MO service meta-model
  - Accommodate dynamic binding
- Model needs to be stored in a dynamic way
  - Capture meta-model as COM objects?
- Introduce optional separation of concerns
  - Better support for reuse
  - Better support for analysability
  - Can combine concerns where needed for flexibility or performance
- Could extend harmonised architecture to also cover SOIS services
  - Long-term future

Components and Services

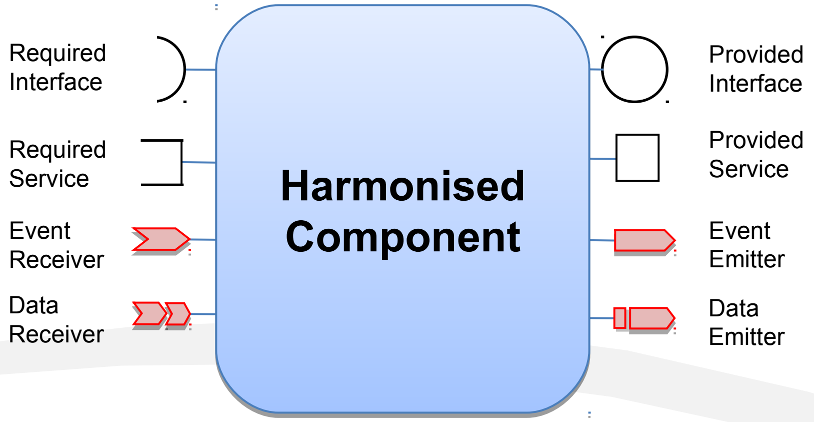
- A component interface and a service are on different semantic levels
- Component interfaces (as defined by the OSRA)
  - Describe *what*
  - For example
    - An attribute
    - An event
  - Bindings bind a *thing* to a *thing*
    - e.g. an attribute to an attribute
- Service interfaces (as defined by MO and, to a lesser extent, SOIS)
  - Describe *how*
  - For example
    - Parameter service
    - Event service
  - Bindings bind a *mechanism* to a *mechanism*

The harmonised component model

- Start with the OSRA component meta-model
- Rationalise and improve type system
- Relax constraints on separation of concerns
  - Components which obey separation of concerns are marked as “pure”
- Add services as a first-class part of a component specification
  - Service operations similar to those in the MO service meta-model
  - Introduce different types of service bindings permitting dynamism
- Introduce standard component services
  - Reused from MO with minor modifications
  - Action, Parameter, Event, Data
  - These map onto other component model artefacts (e.g. interface attributes)
- Standard framework services introduced to permit introspection and dynamic binding (where required)
- Also introduce framework services for component persistence

Components in the HCM

- Extend component model to include services
- Example graphical notation



- Binding of components is more of a challenge using OSRA-style tooling
- Need to support more dynamic bindings
  - Introduction of new views
- Tooling expected to be used across development and operations
- Operational view of the spacecraft identical to development view
  - Still based on components

Implications of the HCM

- Model is a complete snapshot of the system
- All types of functionality appears as a component
  - Including scripts and OBCPs (OBOPs and OBAPs)
- History of system is captured in the model
  - Audit trail
  - Includes the addition or removal of scripts
- Model supports assurance
- Allows seamless interaction with simulation
  - During development and operations
- Model can be used to incorporate SOIS services
- The monolithic Execution Platform shrinks in size considerably
  - Most elements can be represented as components
  - Can **reuse existing implementations** wrapped and modelled as components

Analysis outcomes and recommendations

Analysis outcomes

- Architectural design process brought to light inconsistencies between the technologies
  - Should be addressed to promote interoperability
  - Even if consolidated/harmonised architecture is not used
- Suggested changes to all three
  - Many issues were common across all technologies
- Some changes already captured in the scope of other activities
  - e.g. issues with SOIS

Recommendations (1)

- Recommendations for the OSRA
  - Rationalisation of the type system
  - Parameter access for array slices in Execution Platform interface
  - Extending operation argument modes to support interaction patterns
  - Simplification of observability and commandability
  - Consider an alternative approach to commanding and forwarding services
- Recommendations for MO
  - Extension to the M&C Parameter Service to support more parameter types
  - Extension to M&C Parameter and Aggregation definitions
  - Rationalisation and improvements to the type system
  - Separation of the service and object meta-model from services (inc. MAL)
  - Consider restructuring documentation considering the various stakeholders who will need to read it

Recommendations (2)

- Recommendations for SOIS
  - Consider the position, role and interface to DDPS
  - Document the reference dynamic architecture, especially in the case of scheduled subnetworks
  - Document the expected use of SOIS services for time distribution and synchronisation (both static and dynamic architecture)
  - Rationalisation of the EDS type system
  - Alignment of the EDS component model with the OSRA
  - Generalisation of the Packet Store Service
  - Alignment of the File Management Service with MO
  - Alignment of the Time Access Service with MO
  - Drop the Message Transfer Service in favour of MAL

Other recommendations

- Some minor recommendations for PUS-C
  - Relaxation of contents of automation actions to stop it breaking layering
  - Clarification of definition of Parameter Service
  - Clarification to PFC definition for enumerations
- Some recommendations for CCSDS
  - Develop a single, robust, syntax-independent type system which can be used by multiple standards and encourage its use
  - Develop a single, domain-specific ontology which can be used by multiple standards and encourage its use

Consolidated architecture prototype

Prototype aims and scenarios

- Explore key areas of the consolidated architecture
- Examine as many areas as possible
  - Focus on architecture rather than implementation accuracy
  - Breadth rather than depth
- Adopt a scenario-driven approach which covers
  - The important User Needs
  - The expected migration approach
- Scenarios
  - MO space-ground interface
  - MO service within a PUS mission
  - Replacing PUS with a full MO services-based implementation
  - Model-based development with tooling support
  - Automation and movement of functionality between flight and ground

Prototype approach

- Iterative approach across design and implementation phases
- Early iterations focus on prototyping and working on the detailed design
  - De-risking parts of the architecture and technologies
  - Familiarisation with tooling
- Later iterations focus on implementation
  - Including prototyping of tooling
- Meetings at start/end of iterations for review and planning
  - Including the customer in all meetings
- Leverage existing work
  - TASTE toolchain
  - OSRA/COrDeT tooling
  - OPS-SAT MO adapter for SCOS 2000
  - ESA MO implementations: MAL, tooling, space packet bindings

Next steps

- Prototyping so far has focused on investigating architectural concerns
  - Onboard implementation using components
  - Including both MO and PUS approaches alongside each other
  - Utilising MO within a component-oriented architecture
- This is leading to development of a detailed design
  - Detailed design review by the end of November
- Next steps are to
  - Expand architectural prototyping
  - Prototype elements of development toolchain including OSRA ↔ MO interaction
  - Increase coverage of prototype MO and PUS services
  - Add automation support and ground HMI to improve demonstration value
- Lessons learned will be captured alongside current recommendations

Summary and conclusions

Conclusions (1)

- MOSS examines three technologies starting with their user needs and requirements
  - Shared objectives
  - Overlapping scope
  - Complementary approaches and concepts
- A consolidated set of user needs and requirements is produced by combining the three
- Results in a vision for a consolidated and harmonised architecture
  - Spanning complete space-ground systems
  - Spanning development and operations
- Architectural design focuses on near term evolution
  - Consolidated architecture
  - Offers significant value for limited changes to technologies
  - Flexible migration paths limiting impact on existing implementations

Conclusions (2)

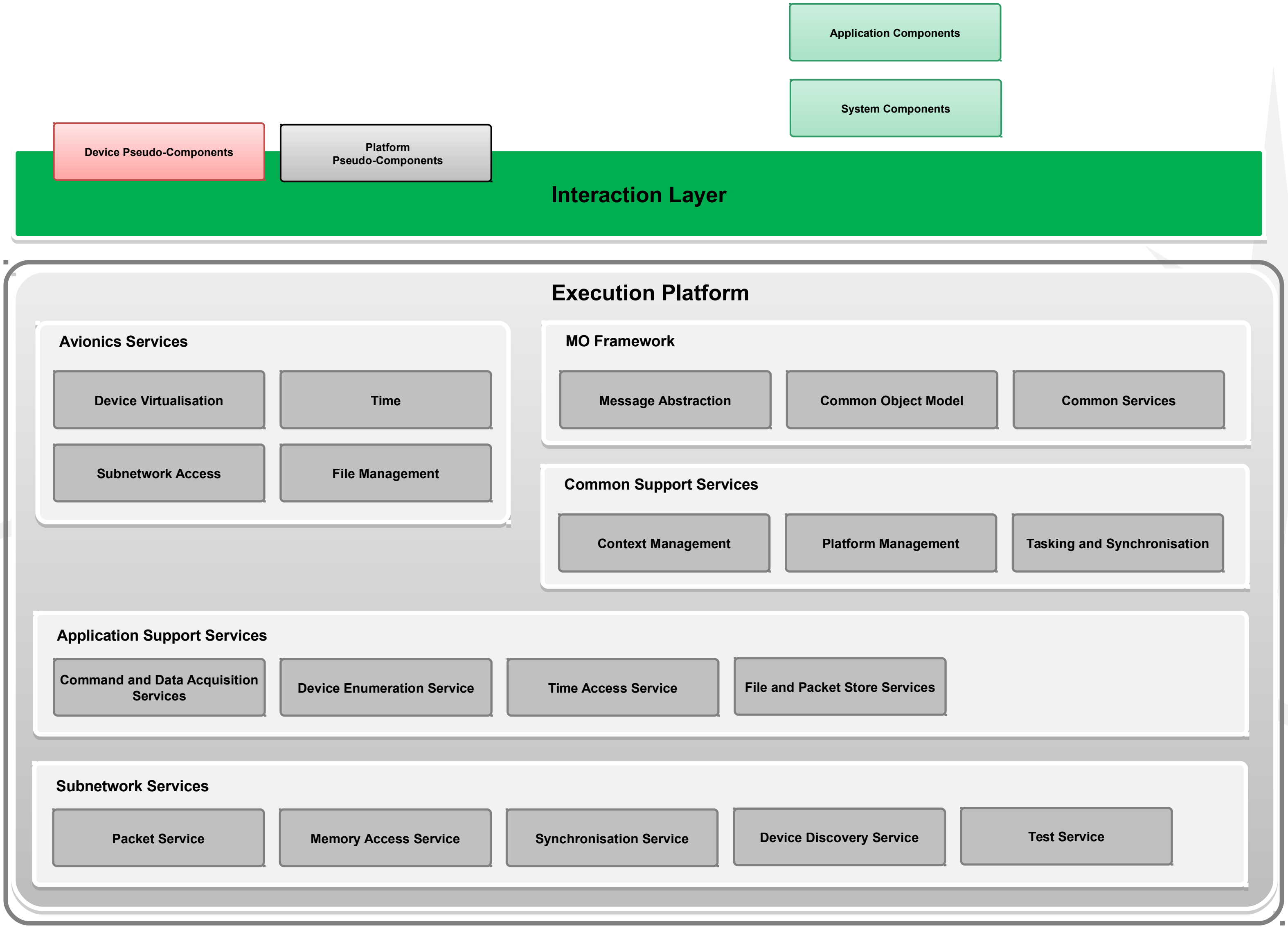
- Longer term Harmonised Architecture is outlined
  - Greater value obtained
  - Requires more work in defining and prototyping a harmonised component model
  - Tooling support is crucial
- Prototyping aims to investigate the highest risk areas for consolidation
  - Breadth rather than depth approach
  - Iterative development used to control risks and obtain maximum value
- Feedback and recommendations made on each of the technologies
  - Additional feedback to PUS-C
  - Also feedback for CCSDS as a whole
- Will be demonstrating ideas using the prototype
- Will be making an argument for harmonisation based on top-down analysis of operability and development user needs
- Will be updating recommendations and feedback at the end of the study

Backup slides

Operations

- Service and component operations are far less clear
  - They *look* the same (or similar)
  - The could possibly be coerced into performing the same function
  - That does not mean that they **should**
- Invoking a service operation you *may* get to choose the provider
  - In a location-independent way
  - Forms the basis of dynamic binding
  - Publish-subscribe permitted
- Invoking a component operation you **never** get to choose the provider
  - Key part of static binding
  - Publish-subscribe does not make semantic sense
- Some other differences between MO/OSRA
  - e.g. parameters can be attached to all messages such as ACK and UPDATE

Harmonised architecture EP



OHB SYSTEM RHEA bright ascension