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Beyond Open Architecture Compliance: How Design-for-Integration Solves Interoperability for Sensors on Legacy Aircraft

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Presentation Objectives

Present research problem and current vector.

Solicit data from the community for sensor integration successes and failures from open architecture programs on legacy platforms.

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“Success no longer goes to the country that develops a new technology first, but rather to the one that better integrates it and adapts its way of fighting.[1]”

Former Secretary Jim Mattis

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What are Open Architectures?

Better Buying Power 3.0 2015

National Defense Strategy 2018

National Defense Auth. Act FY 2017

Software Interfaces

Modularity

Environment Specification

Adaptive Acquisition

Hardware Interfaces

Data Rights

FACE
Future Airborne Capability Environment

Open Mission Systems

SOSA
Sensor Open Systems Architecture

Others

Competition

Tech Insertion

Reuse

Incremental Upgrades

Open Systems Approach is standardizing architecture elements, providing benefits to modern aircraft

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Research

Problem Statement:

Existing Department of Defense open standards do not enable modern sensor subsystem interoperability with legacy subsystems, restricting mission capabilities.

Research Plan Summary:

1. Analyze sensor integration data from open architecture legacy platforms to identify top factors of integration scope growth.
2. Identify best machine learning algorithms for learning sensor behavior.
3. Identify best methods for accounting for dynamic aircraft and sensor environments in machine learning-based sensor controllers.

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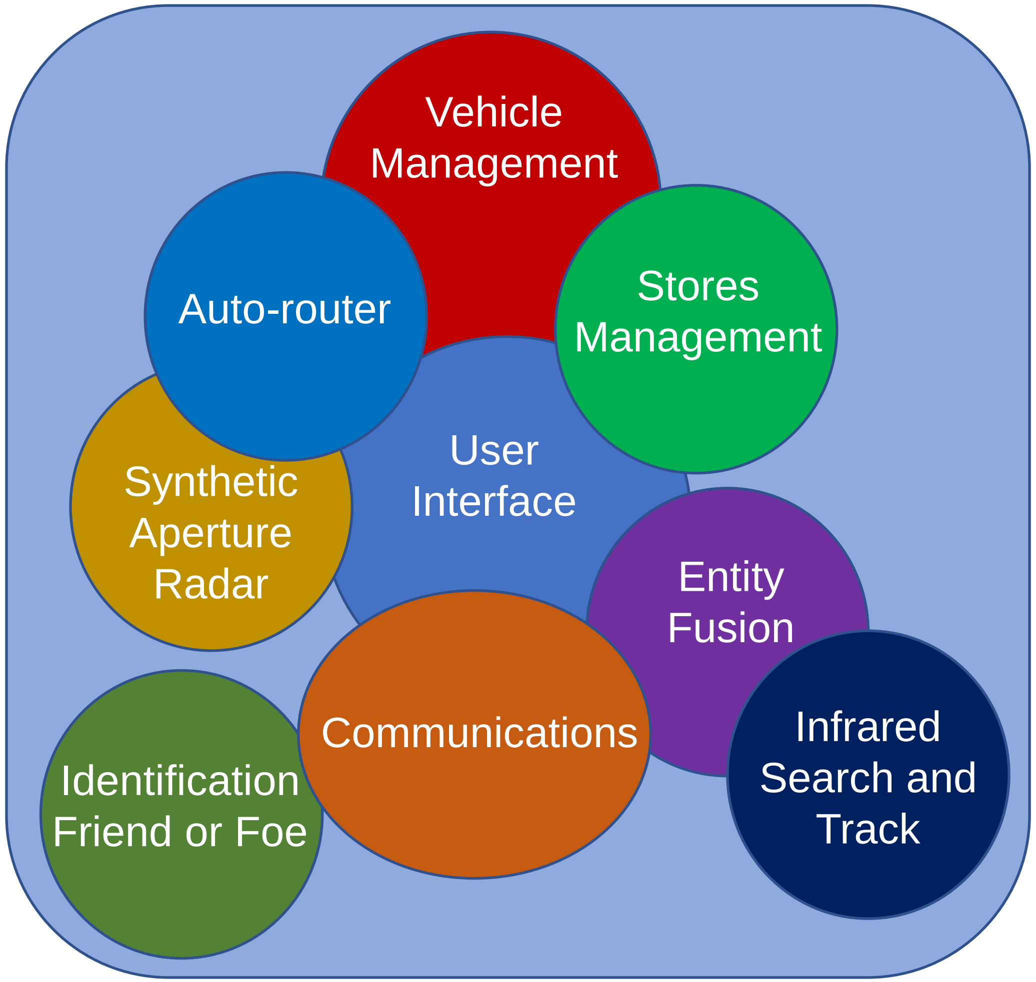
Legacy Architectures



Open Architectures

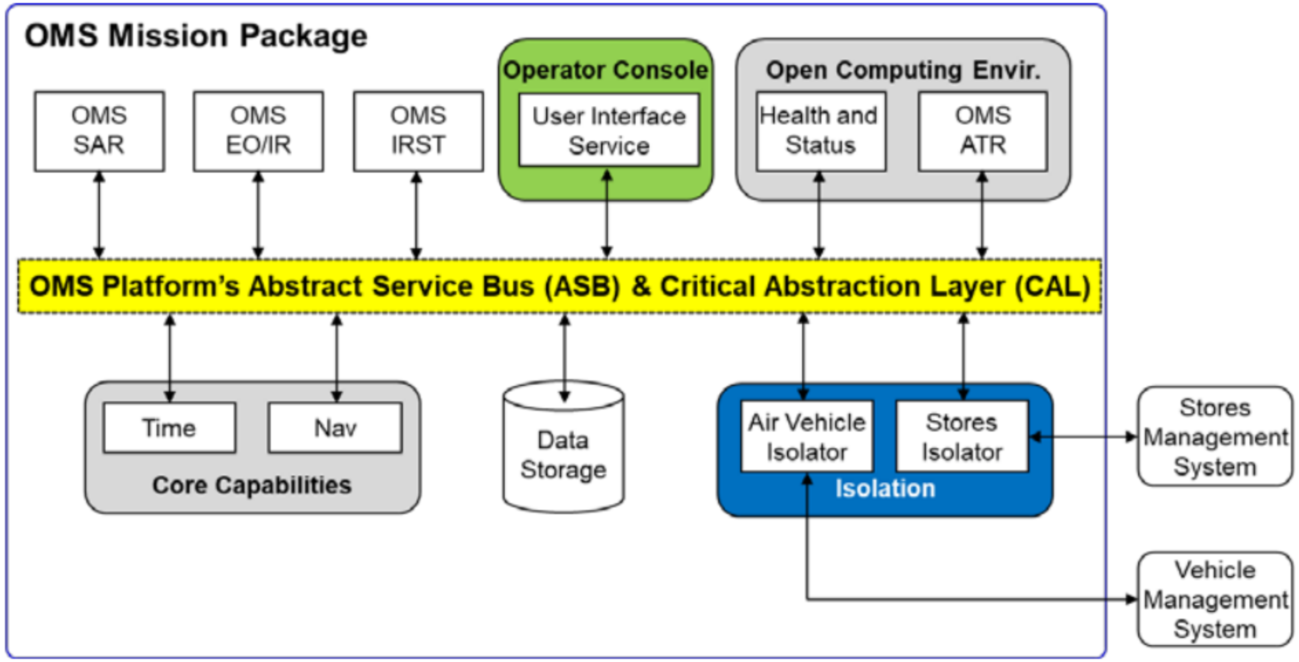


Fig. 1. Open Mission Systems [2]

Acronym Legend
Open Mission Systems (OMS)
Synthetic Aperture Radar (SAR)
Electro-Optical Infrared (EO/IR)
Infrared Search and Track (IRST)
Avionics Tech Refresh (ATR)

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Monolithic architectures limit upgradeability when compared to modular open architectures

Open Aircraft Architectures

Legacy Aircraft Architectures

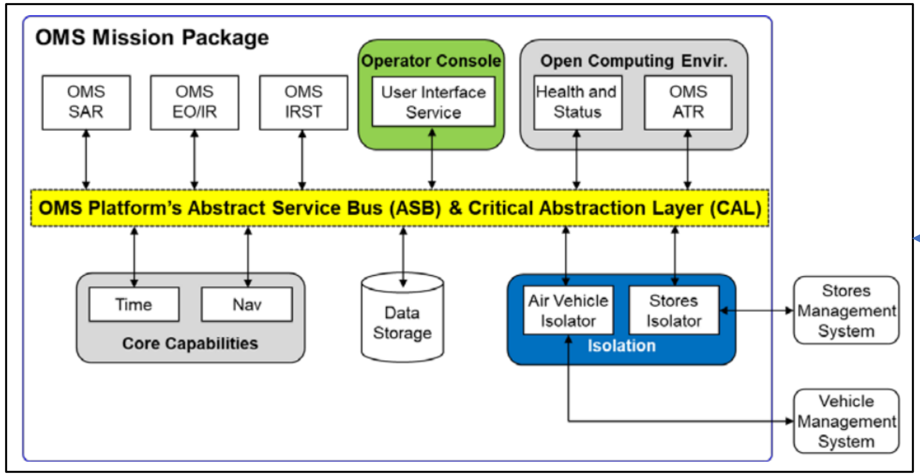

Fig. 2. Open Mission Systems [2]

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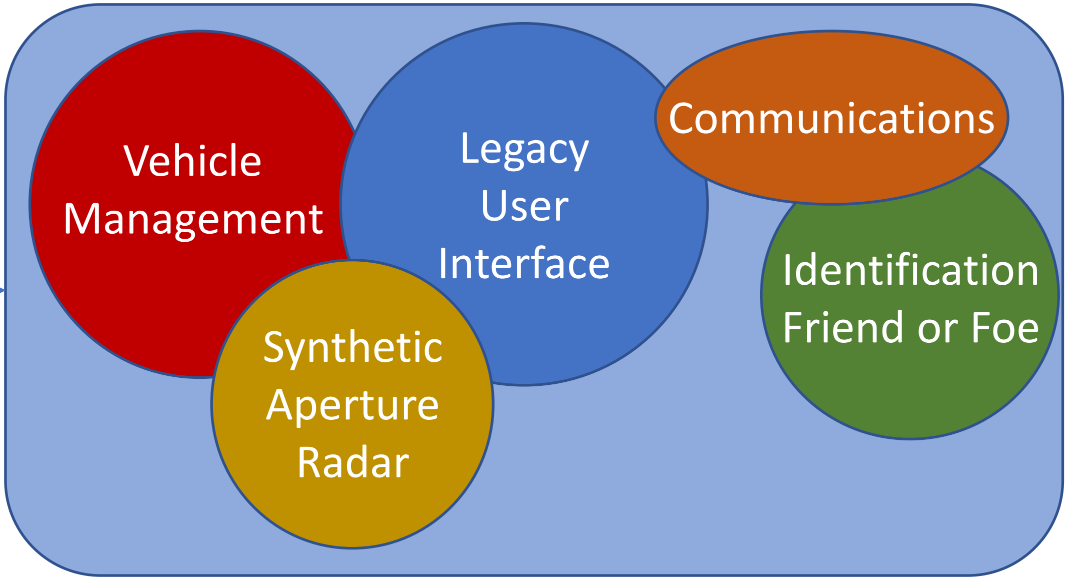

Custom Software

Open Aircraft Architectures	Legacy Aircraft Architectures
1 Pulse Per Second and Precision Time Protocol	16 Hz system time updates
Electronic Order of Battle Load	Electronic Order of Battle Updates
10 Hz Latitude/Longitude	4 Hz Latitude Longitude
File Transfer Protocol/Network File System to media	Custom file system
Geolocated tracks	Detected frequencies and vectors
1Hz Health and Status	Real-time 64 Hz heartbeat

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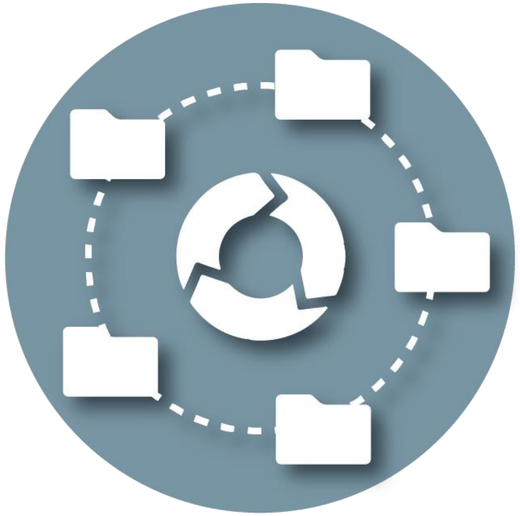
Integrating open architecture-based sensors with legacy aircraft require data transformations that drive scope growth

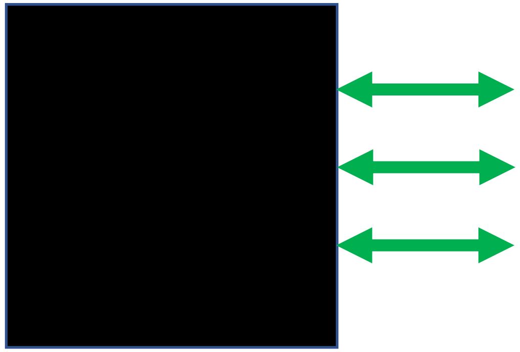
Design Documentation Examples

Best → Methodically Challenging → Insufficient Information



Model-Based Systems Engineering

Traditional paper documentation



Black box only, missing critical design/interface documentation

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Legacy aircraft design are frequently not well documented

Standardization Across Specification Levels

Application Behavior	✗	Startup/Shutdown, Classified Data Erase, EOB Load, Track Report, Time/Nav
Software Modules	✓	System Manager, Security Services, Task Manager, Nav Data Service
Software Interfaces	✓	POSIX, FACE APIs, OMS Critical Abstraction Layer
Data Syntax	✓	XML, OMS Schema, FACE Data Models
Software Environment	✓	Operating Systems, Containers, Virtual Machines
Hardware Management	✓	SNMP, IPMI
Hardware Interfaces	✓	Ethernet, serial, discrete, RF, Fiber Optic, thermal, Slot profiles, electrical, mechanical

Sensor interfaces are being standardized at all levels except application behavior.

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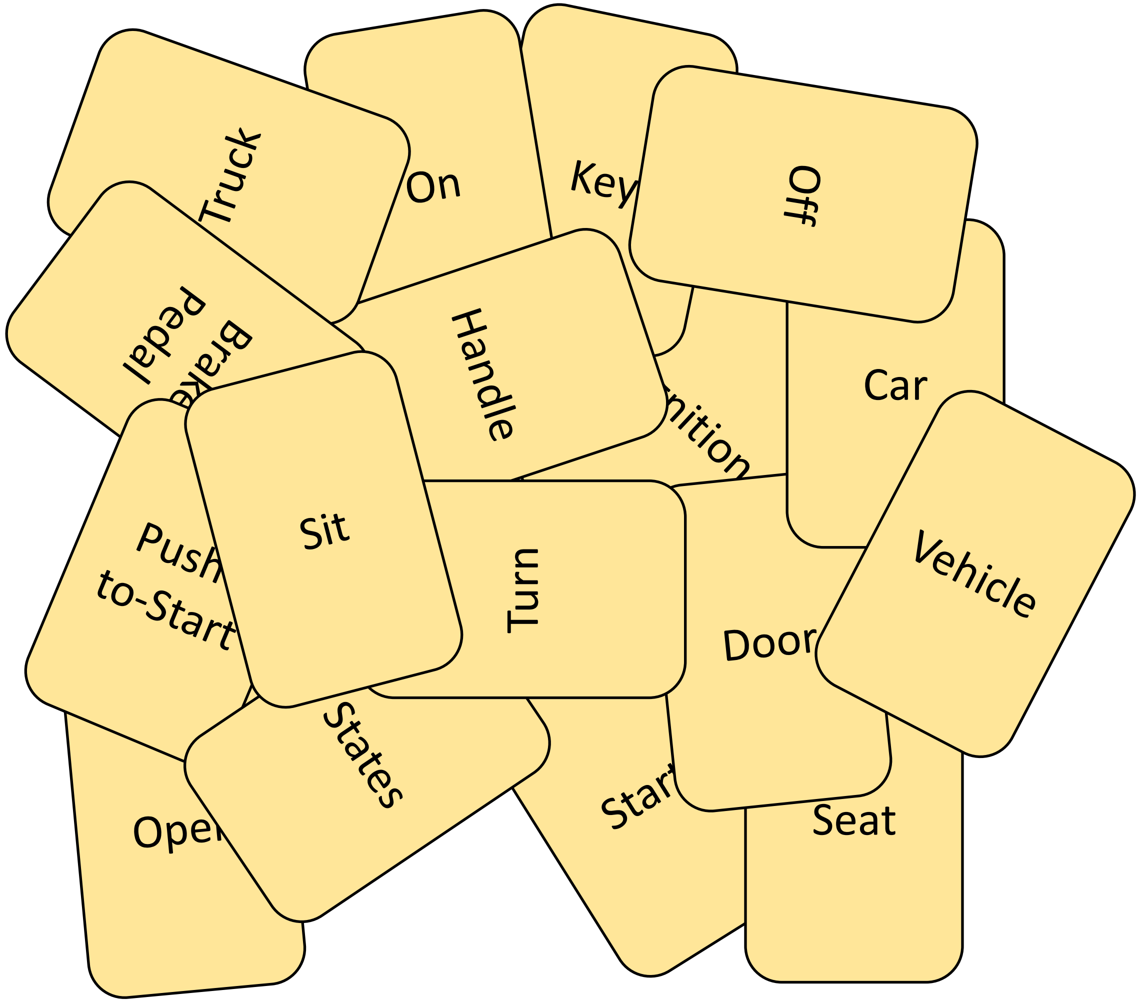
Concepts



Structure

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        elementFormDefault="qualified">
    <xsd:element name="car" type="vehicle"/>
    <xsd:complexType name="vehicle">
        <xsd:sequence>
            <xsd:element name="door"   type="state"/>
            <xsd:element name="ignition" type="state"/>
            <xsd:element name="key"  type="keyType"/>
            <xsd:element name="operatorActions"    type="actions"/>
        </xsd:sequence>
    </xsd:complexType>
    <xsd:complexType name="actions">
        <xsd:choice>
            <xsd:element name="open"/>
            <xsd:element name="close"/>
            <xsd:element name="press"/>
            <xsd:element name="depress"/>
            <xsd:element name="turn"/>
        </xsd:choice>
    </xsd:complexType>
    <xsd:complexType name="state">
        <xsd:choice>
            <xsd:element name="on"/>
            <xsd:element name="off"/>
        </xsd:choice>
    </xsd:complexType>
    <xsd:complexType name="keyType">
        <xsd:sequence>
            <xsd:element name="Push-to-Start"
                type="xsd:boolean"/>
        </xsd:sequence>
    </xsd:complexType>
</xsd:schema>
```

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Modeling, specifying behavior enables interoperability

Design for Integration

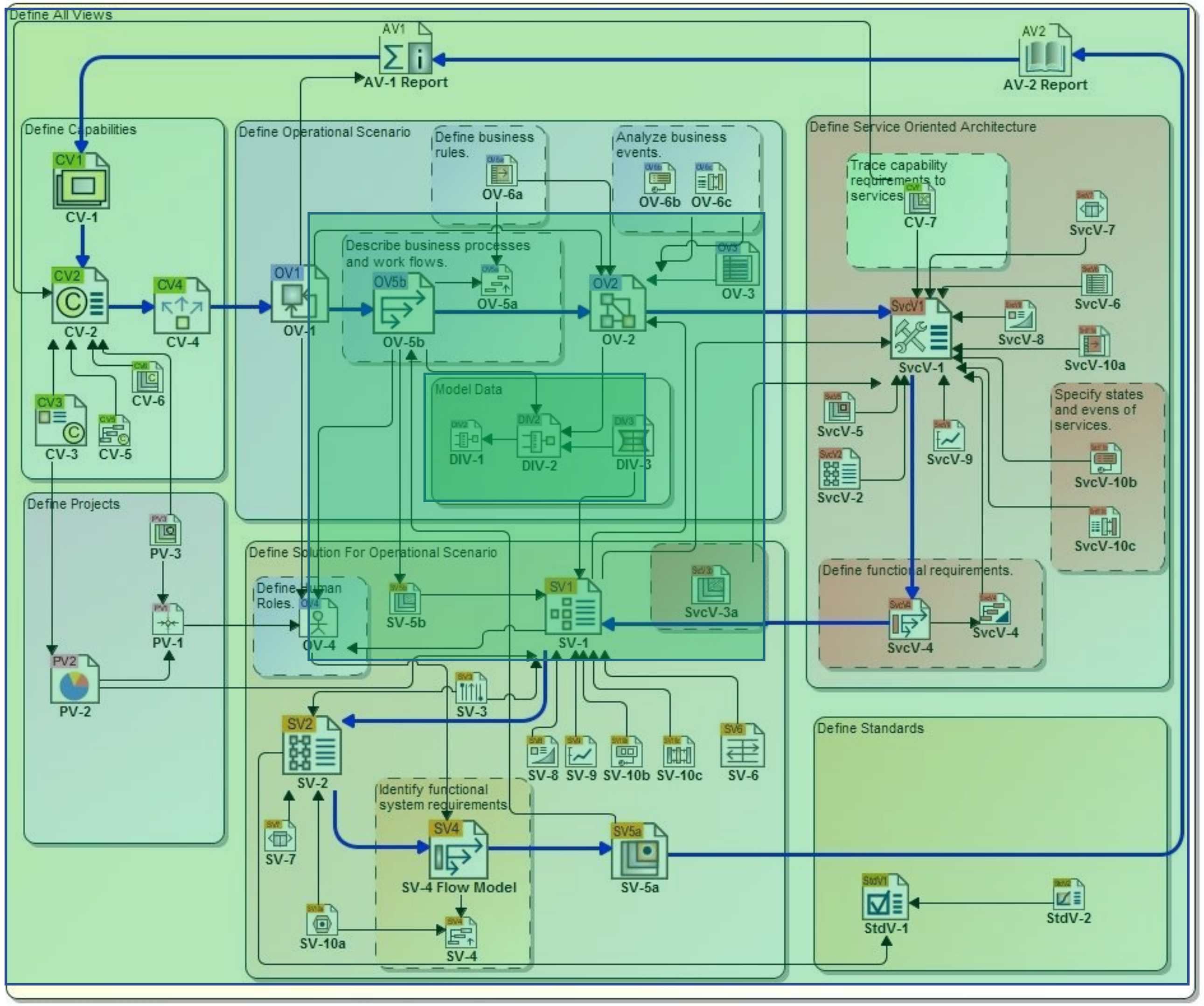

Fig. 3. DoDAF 2.0 viewpoints and views [3]

Start design by capturing legacy data exchange requirements

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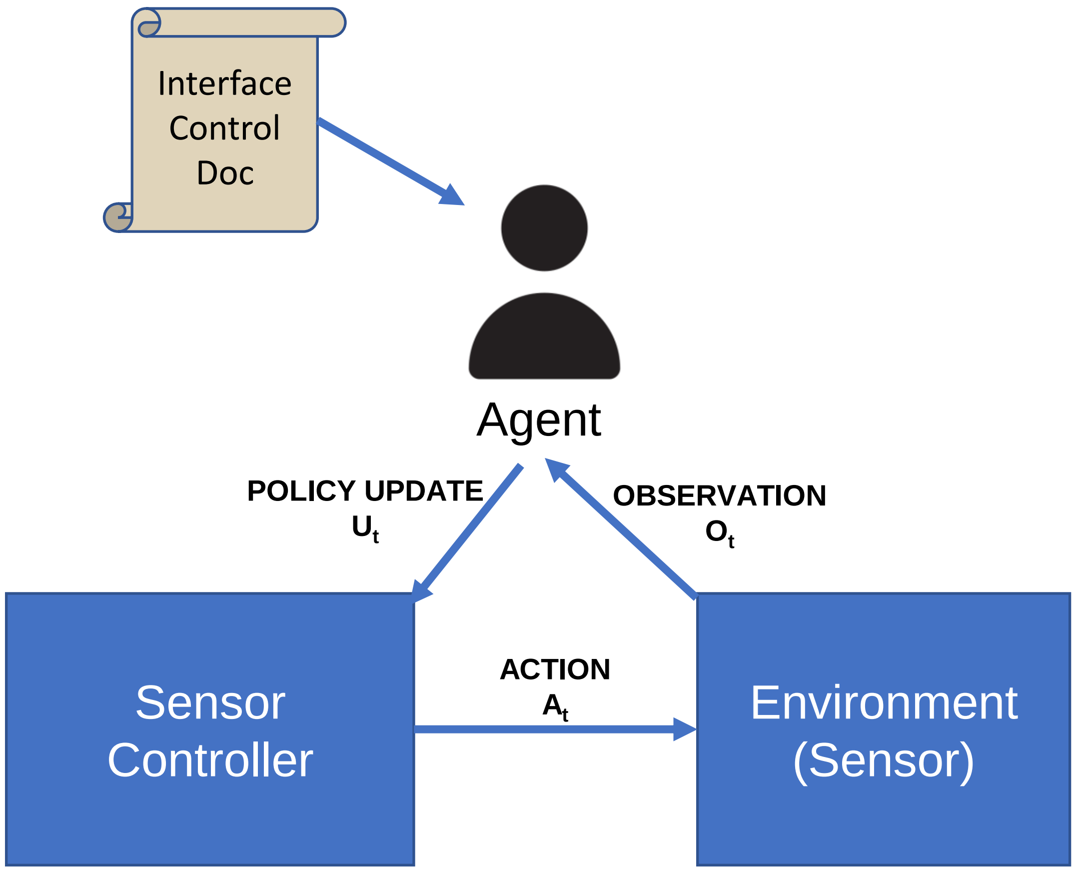
Manual Integration



Interface Learning

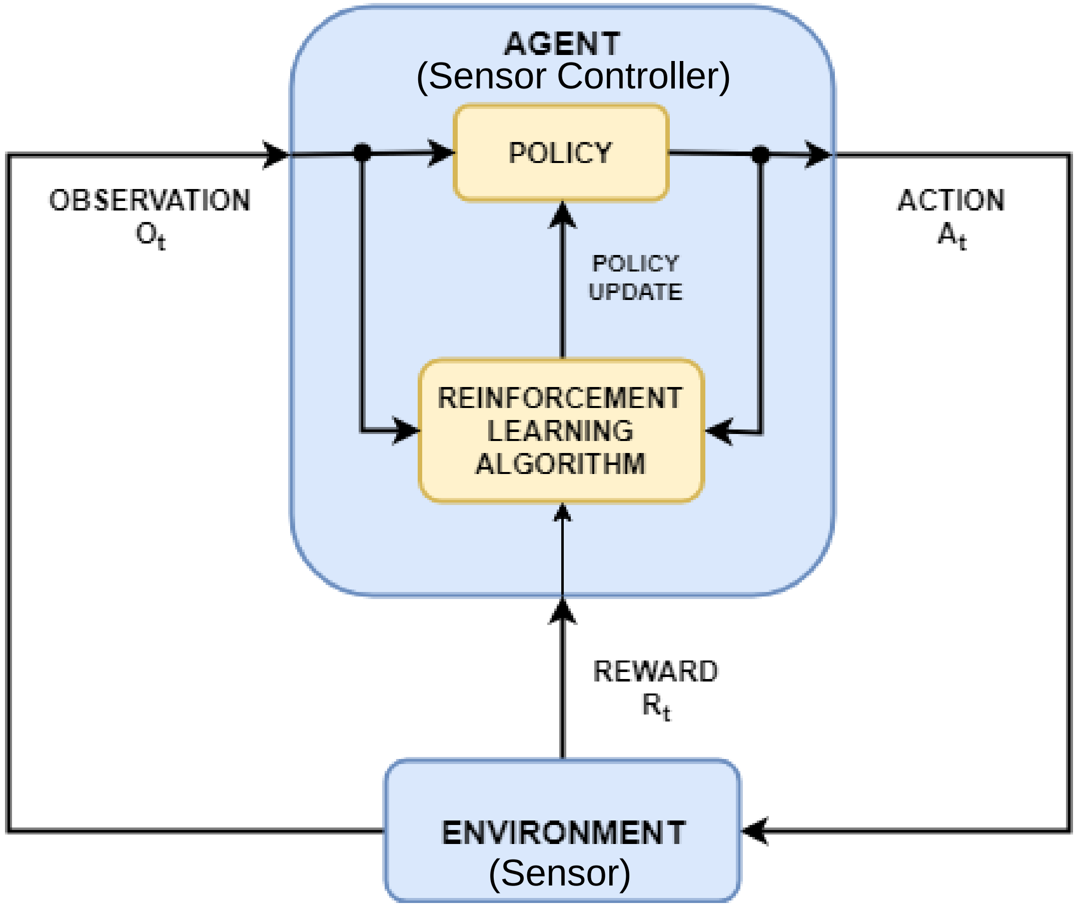


Fig. 4. Reinforcement Learning Scenario. Adapted from [4]

Reinforcement learning algorithms provide potential departure from manual integration

Machine Learning Algorithms

- API Sequence Learning Techniques
  - Recommender Algorithms, Deep Natural Language Processing
- Reinforcement Learning
  - Q-Learning, Deep Q-Network, Double Deep Q-Network, Instance-Based Learning
- Dynamic Environment
  - Communication failures, sensor hardware faults, non-deterministic response times

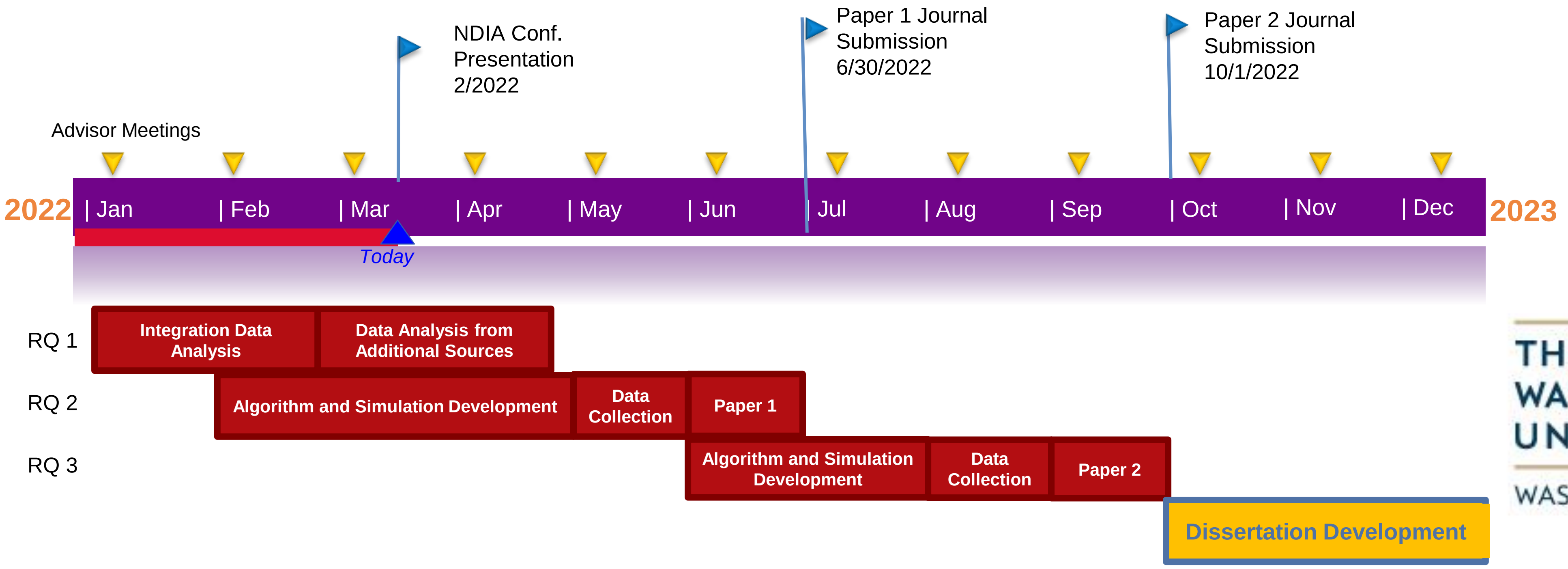
Algorithms for learning sensor behavior can accelerate integration but will need to be able to handle dynamic environments.

2022 Research Plan

Research Question 1: What are the top factors that impact sensor interoperability?

Research Question 2: What are the best algorithms to apply to machine learning of sensor behavior?

Research Question 3: What are the top methods for accounting for dynamic aircraft and sensor environments for machine learning-based sensor controllers?



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Summary

Sensor interoperability enables upgrades at the speed of relevance, but we need to overcome monolithic architectures, data transformation complexity, and a lack of design documentation.

Application behavior standardization, data-centric design, and interface learning are potential solutions for enabling interoperability.

Research will deliver reinforcement learning algorithms that augment open standards to enable sensor interoperability.

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Next Steps

Data Needed

Feedback Needed

Ideas for Deep-dives Welcomed

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Figure References

[1] J. Mattis, “Summary of the 2018 National Defense Strategy of The United States of America,” White House, Washington, DC, USA, 2018.

[2] “Open Mission Systems (OMS)”, *Virtual Distributed Laboratory*, 2021. [Online]. Available: https://www.vdl.afrl.af.mil/programs/oam/OMS_Marketing.pdf. [Accessed: 10-Oct-2021].

[3] "DoDAF 2.0 viewpoints and views", *CATiA No Magic*, 2021. [Online]. Available: https://docs.nomagic.com/display/UPDM2P190/DoDAF+2.0+viewpoints+and+views. [Accessed: 10-Oct-2021].

[4] “What Is Reinforcement Learning", *MathWorks*, 2021. [Online]. Available: https://www.mathworks.com/help/reinforcement-learning/ug/what-is-reinforcement-learning.html. [Accessed: 10-Oct- 2021].

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