Benefits and Limitations of Reliance on an Open Architecture Technical Standard to Meet Expectations of an Open System

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Bottom Line Up Front

- **Industry-wide lessons learned about open systems has motivated a new understanding of what it means to be open**
  - Review of key documents explaining this new understanding
- **It is possible to conform with open standards but not actually meet the expectations of an open system**
  - Use the FACE™ Technical Standard to learn about these gaps
  - Lessons learned from demonstrations revealed cases leading to remedies
- **Recommend a set of best practices to meet the spirit and intent of an open system while conforming to an open standard**
  - Some cases can be handled by changing the standard, but most are associated with how the standard is used
- **Suggest future areas of study to further close the gaps**

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Topics

- **Attributes of an Open System**
  - Policies, Guidance, Directives
- **Demonstration Experience and Lessons Learned**
  - Summary of Integrated Processing Demonstrations
  - Systems Engineering and Context Development
  - Data Modeling
  - Transport Services
  - Tool Usage and Integration Modeling
  - Third Party Interaction
  - Legacy to FACE Interfaces
  - Conformance
  - Software Metrics
- **Summary of Best Practices**
- **Conclusions**
  - Areas of future study and acknowledgements

Key Attributes of an Open System

- **Government controls relevant interfaces**
  - Needed to maintain competition for component developers and integrators
- **Develop in accordance with an Open Standard**
  - The Future Airborne Capability Environment (FACE™) Technical Standard was used for this work
  - Results generally applicable to other open standards
- **Allow for cost effective, rapid insertion of commercial technology**
- **Highly cohesive, loosely coupled, severable components**
  - Defines the competitive boundaries
  - Subject to program-specific trade studies

Modular Open System Approach (MOSA)

- **Enhance competition**
  - Enable innovation while driving down cost
  - Results generally applicable to other open standards
- **Incorporate Innovation**
- **Facilitate technology refresh**
- **Enable cost savings and cost avoidance with reuse**
- **Improve interoperability**

Enforce an Open Standard and an Open System Acquisition Approach

Integrated Processing Demonstrations

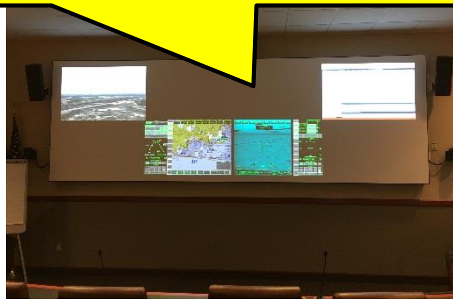
	Demo #1	*Demo #2/2A*	*Demo #3*
Dates	June 11, 2015	September 17, 2015 (#2) January 18-20, 2016 (#2a)	Aug 31 – Sep 1, 2016
Location	Mesa, AZ	Mesa, AZ (#2) Arlington, VA (#2A)	Ridley Park, PA
Number of FACE UoPs	12	18	21
Partners	3 Different Boeing Organizations 1 Sikorsky Organization 1 Lockheed Martin Organization	3 Different Boeing Organizations 1 Sikorsky Organization 1 Lockheed Martin Organization	3 Different Boeing Organizations 1 Government Organization 1 Lockheed Martin Organization 3 Other Companies
Major Accomplishments	• Established "working together" approach • Established/updated tools for FACE development and integration • Interoperability of Transport Services • Real-time simulation • Determined method to interface with the simulation environment • Tested use of FACE Integration Model • Numerous lessons learned on how to integrate using the FACE Technical Standard	• Increased number of applications by 50% • Free-form, hardware-in-the-loop simulation • Software reused from legacy programs • Compatibility of FACE Transport Services • Reduction in integration time through open and shared data models • Plug and play different applications against the same FACE Data Model • Going from an Interface Control Document to FACE Data Model without supplier involvement	• 9 new applications (reused 12 from previous demonstrations) • Increased 3rd party involvement • Tested a new tool to show that integration does not depend on an integrator's toolset • Three different competing applications using the same Data Model • 19 of 21 applications running on flight-qualifiable hardware • Sufficient proof that the FACE approach reduces software development and integration cost

Demonstration Objectives

1. Evaluate interoperability and performance
2. Identify and test reuse opportunities
3. Explore integration using the FACE approach
4. Examine implications to the SW life cycle
5. Reduce risk for vertical lift mission systems
6. Collect and disseminate lessons learned

Photos of Demonstration Equipment

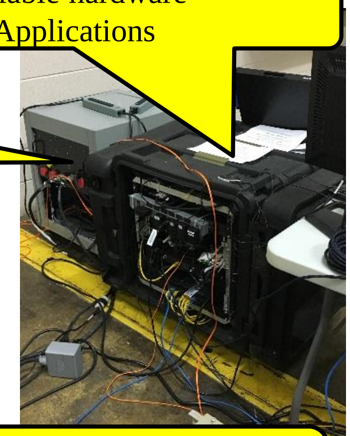
- Demonstration venue
- Used 8 simultaneous video feeds to highlight key aspects of the demo



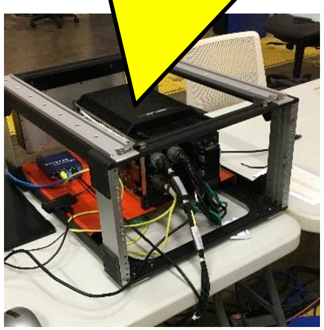
- Portable cockpit
- Simulated threat and friendly entities

- Partner flight qualifiable hardware
- Hosted 5 Demo #3 Applications

Partner radio equipment



- Flight qualifiable hardware
- Hosted 14 Demo #3 Applications



- Multiple digital map stations

Partner Targeting Sensor

Additional partner radios

Partner communication intelligence simulation

Free-Form, Real-Time, Hardware-in-the-Loop Simulation

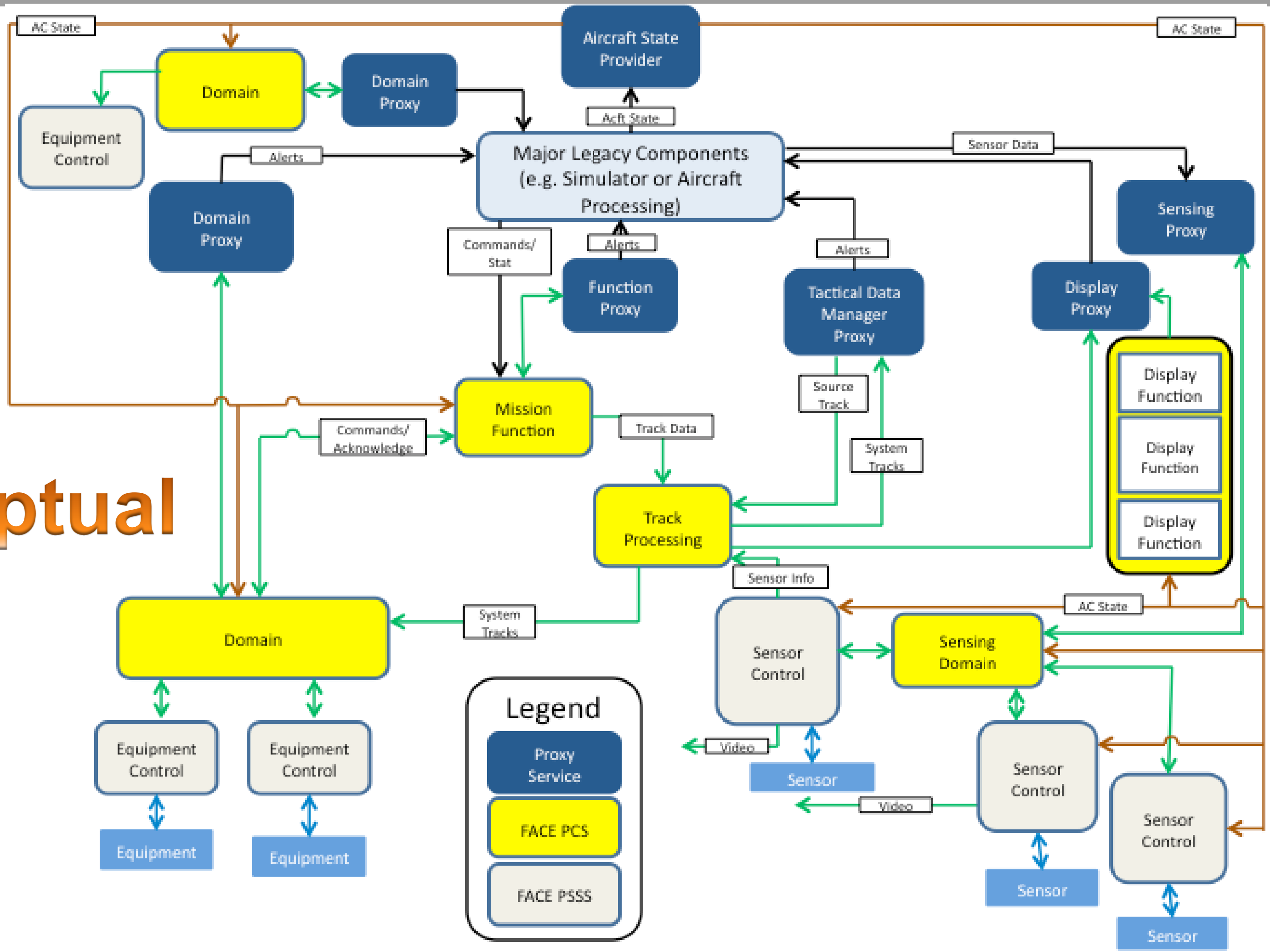
Systems Engineering

- **Joint Common Architecture (JCA) used as a guide**
  - 10 of 21 Units of Portability (UoPs) aligned to the JCA
  - Non-aligned components for direct reuse from legacy applications
- **Open System Implications**
  - Where to draw the component boundaries
  - Too broad creates a “winner takes all” situation leading to vendor lock
  - Too detailed leads to unacceptable administrative burden and cost

Enable Affordable Competition

Context Development

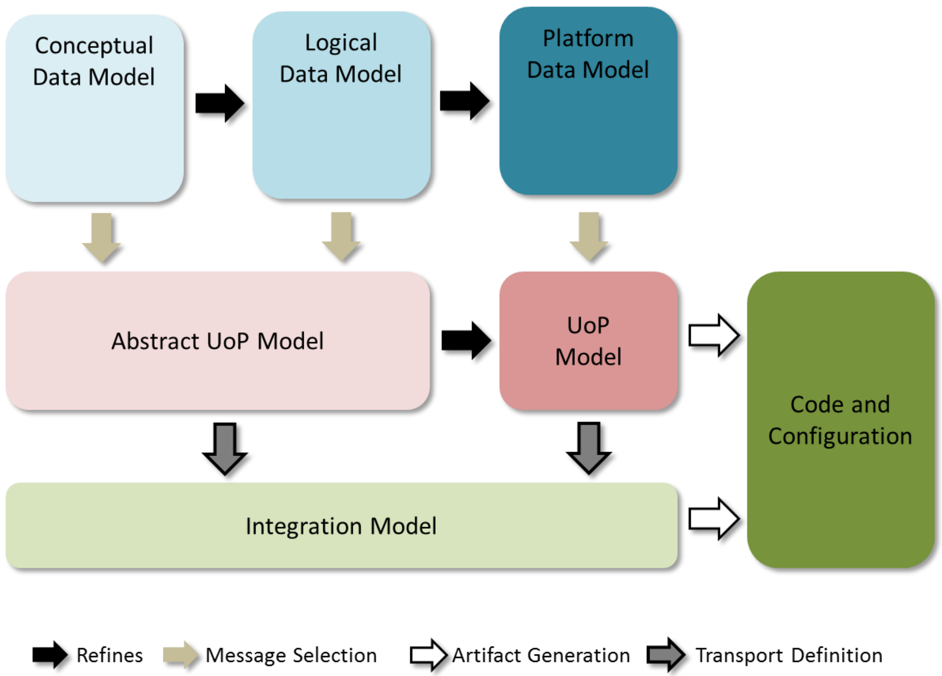
Conceptual



A Context Interaction Diagram Facilitates Integration

Data Modeling

- Helps enable MOSA with data models defining the key interface boundaries
- Government will need sufficient data rights to data models to achieve competition
- Data models replace the SW aspects of Interface Control Documents (ICDs)



Data Model + Integration Model = Tremendous Savings in Integration Cost and Risk

Data Modeling Lessons Learned

- **Does not require a steep learning curve**
  - Leverage experience, adopt object-based mentality
- **Major enabler for Open System acquisitions**
  - Element that instantiates key interfaces
- **Successfully demonstrated three different digital maps using the same UoP Supplied Model (USM)**
- **Easy to convert vendor-supplied ICD to a USM**
  - Could operate vendor-supplied hardware with little to no support from the vendor of that hardware
- **Noted minor challenges with the Shared Data Model**
  - Submitted to FACE Consortium – will be fixed with maturation

Data Modeling is Critical to Achieve Open Systems as Intended

Transport Services

- **Auto-Generated from data models and integration model**
  - Same type of transport service facilitates integration
- **The FACE Technical Standard allows proprietary transport services**
  - Use compromises Open System attributes (see next slide)
- **Experimentation with mixed transport services**
  - Different transport services using the same “pure” implementation of the Data Distribution Standard (DDS) were interoperable
  - Attempt to use a proprietary transport did not work due to payload incompatibility issues
  - By Demo #3, three different transport services were interoperating within the system in real time with no performance degradation (none had developer or integrator proprietary content)

Open System Concern with Proprietary Transport Services

- **Proprietary Transport Service (TS)**
  - Proprietary content from commercial middleware or operating system vendors is acceptable if it implements widely used standards, such as DDS and POSIX
  - Risk of vendor lock if proprietary capabilities from a developer or integrator are in the TS
- **A proprietary TS may be necessary to meet requirements**
  - If the capability should be implemented in the TS, it contains capability broadly applicable to most, if not all components (e.g. reliability, security)
  - The licensor of the proprietary TS can charge fees for its use
  - In this case, the Government can define the interfaces, but the owner of the proprietary TS would control the interfaces (open system problem)
- **FACE Technical Standard Edition 3.0**
  - Recognized this issue and defined a Transport Protocol Mechanism (TPM) to enable interoperability in the same system using different TSes
  - Components that do not use the proprietary TS would not have the proprietary capabilities (complicates systems engineering and integration)

Tool Usage and Integration Modeling

- Used 3rd party tools for FACE applications
- Internal tools used for implementation of the integration model (not available in the 3rd party tools) and auto-generation of Transport Services
- Used two different internal tools to demonstrate tool independence for the demonstrations
  - LM-Sikorsky tool used for Demos #1, #2, and #2A
  - Boeing tool used for Demo #3

GME

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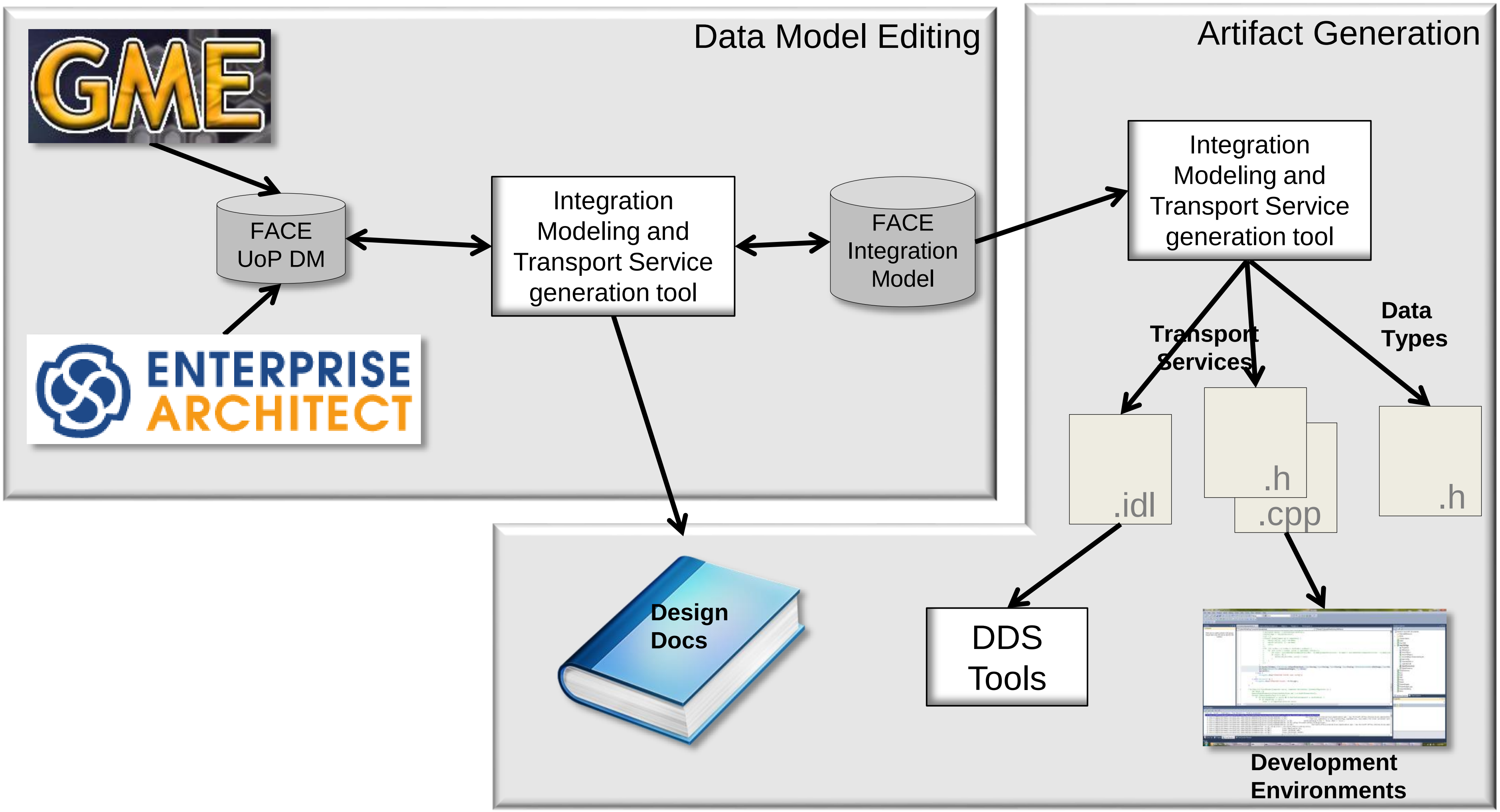
Tools Overview

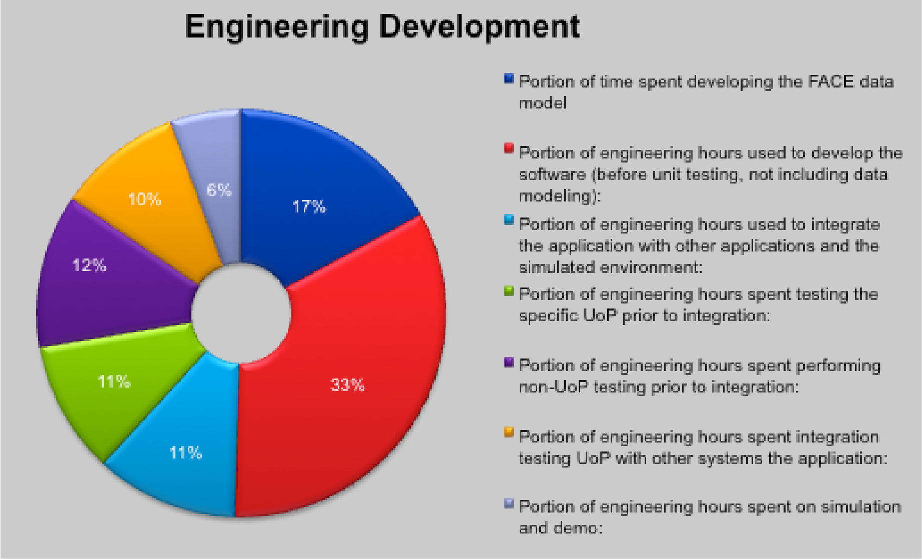


Additional Lessons Learned

- **Third Party Interaction**
  - Joint ownership of data models delivered to the US Government
  - Integrator created TS source code from data models and gave to developer
  - No source code used by the integrator for integration
  - Component developer had choice of running software on their own hardware or providing the executable to the integrator (both used)
- **Legacy to FACE Interfaces**
  - Successful application of proxy services between simulator (used Common Simulation Framework) and FACE UoPs
  - Same approach can be used to incrementally upgrade aircraft to the FACE Technical Standard
- **Conformance**
  - Best to plan upfront with early involvement of the Verification Authority
  - Easy to complete the Conformance Test Suite (CTS) and Conformance Verification Matrix (CVM) – supporting documentation is cumbersome
  - Need a better way to re-verify UoPs that experience a benign SW change

Software Metrics

- Demo #3 contained 845K SLOC for the 21 UoPs and proxy services
- 669K SLOC was auto-generated from FACE, internal, and DDS tools
- 140K SLOC was reused from legacy programs
- Only needed 36K SLOC of new UoP and proxy software to completely run Demo #3



- Integration done with short weekly calls 2 to 3 months in advance of Demo #3 and only needed two days of face-to-face time to make the demonstration operational

The FACE Approach Reduces SW Development Cost and Risk

Recommended Best Practices

1. Component boundaries need to balance competition and cost
2. Procuring agent needs to control key interfaces with appropriate data rights, but allow for developer collaboration
3. Use a Context Interaction Diagram
4. Make SW development process changes for FACE implementation, including data model development
5. If ICDs are available, convert SW aspects of them to a data models
6. If possible, avoid TSes that contain developer or integrator proprietary content
7. If a proprietary TS is necessary, then develop a migration plan to eventually become open
8. Implement integration modeling
9. Ensure practical system integration does not depend on proprietary tools
10. Use proxy or mediation services to incrementally upgrade legacy
11. Plan early for conformance
12. Joint ownership of data models with delivery to procuring agent with Unlimited or Government Purpose Rights
13. Integration without source code

Future Areas of Study

- Application and open system implications of model-based engineering
- Effectiveness of Transport Protocol Mechanisms
- New methods to re-verify previously verified software
- Opportunities to leverage open system benefits for more streamlined airworthiness processes
- The extent to which interfaces impact flight controls
- Definition of best practices for safety, security, and health management to avoid need for proprietary Transport Services

THANK YOU!!!

To the technical team who made all of the Integrated Processing Demonstrations successes

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