Certifiable Modular Avionics Software Development using FACE TSS
Using the Future Airborne Capability Environment (FACE) Transport Service Segment (TSS)

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Agenda

• Introduction to FACE
• Introduction to TSS
• Results of RTI implementation
• Upcoming additions to FACE TSS spec
• Research Opportunities
The FACE Consortium is ITAR restricted, however The Open Group FACE Architecture specification is openly published.

This UNCLASS / Distro-A briefing represents the views of RTI and not The Open Group, FACE, NAVAIR, or USAF AFRL.
FACE Approach

The FACE approach is a government-industry software standard and business strategy to:

- Acquire affordable software systems
- Rapidly integrate portable capabilities across global defense programs
- Attract innovation and deploy it quickly and affordably
Transitioning to Open Interface Architecture

* [http://www.forbes.com/sites/darcytravlos/2012/08/22/five-reasons-why-google-android-versus-apple-ios-market-share-numbers-dont-matter/]
The FACE Technical Standard

FACE is a software architecture standard that is designed to reduce the cost of change and maximize software reuse by specifying common APIs in the application software stack.

- The FACE standard is NOT a safety standard
- The FACE standard is NOT a security standard
- The FACE standard is NOT a hardware standard
- The FACE standard is NOT a system architecture standard
- The FACE standard is NOT a mandated standard
- The FACE standard is NOT a plug-and-play standard
Overlap of Capabilities

- FACE Technical Standard, at a minimum, could provide for the intersection of all platform data points
- Applications written to baseline profile would run on all platforms
Current Integration Approach

- Each platform must develop unique software to integrate avionics/SA hardware & software products
- Each platform maintains expertise only for their product
- Each new software block requires an 18-33 month integration cycle
FACE Integration Approach

- Enables Better Buying Power
- Allows Cross platform decision-making
- Lowers acquisition costs

Graphic used with permission from Tucson Embedded Systems, Inc.
Why FACE Initiative?

- DoD Airborne systems are typically developed for a unique set of requirements by a single vendor
  - Long lead times, even for urgent needs
  - Platform-unique designs limit reuse of software and increase cost
  - Creates barriers to competition within and across platforms
- Current DoD Acquisition structure does not support the process of software reuse across different programs
  - Aviation community has not adopted a common set of Open Architecture (OA) standards sufficient to allow the reuse of software components across the DoD fleet
  - Aviation community has failed to enforce conformance to any existing open standards that are in use
  - Platform PMAs are not funded to assume cost or schedule risk of multi-platform requirements

The Future Airborne Capability Environment (FACE) initiative is an approach designed as a response to the DoD aviation community’s problems.
FACE Industry Benefits

- Enables new markets
  - Creates software-centric market opportunities
  - Enables penetration of formerly closed platforms
  - Provides opportunity for software applicability to multiple aircraft types
- Lowers costs of doing business
  - Common standards lower cost and schedule risks
  - Standardization of software interfaces allows for rapid development of capabilities
  - Re-use of software applications enables integrators to increase platform capabilities
FACE Government Benefits

• Aligns with Better Buying Power 2.0*
  – Promote effective competition, achieve affordability, and control life cycle costs
  – Incentivize productivity and innovation in Industry and Government
  – Reduces subsequent software development times through modularity and portability
  – Eliminate redundancy within Warfighter portfolios

• Facilitates Cross-Platform Decision-Making
  – Ability to re-use applications across multiple platforms without cross-platform dependencies
  – No need to invest multiple times for the same capability
  – Common operating environment and data architecture enable system of systems integration and interoperability

*BBP 2.0 was released by DoD in November 2012 and can be accessed at http://www.acq.osd.mil/docs/USD(ATL)%20Signed%20Memo%20to%20Workforce%20BBP%20(13%20Nov%202012)%20with%20attachments.pdf
How FACE Initiative is Different From Previous DoD OA Efforts

- FACE initiative is addressing business aspects in parallel with development of the Technical Standard
  - Analyzed previous OA efforts
  - Developed FACE Business Guide
  - Establish FACE Library to provide the infrastructure necessary to enable the discovery and acquisition of FACE Conformant products
    - Enables the software supplier to control the flow of information
    - Standard defined in sufficient detail to allow robust conformance certification program
- Public-Private collaboration to establish value for both customer and supplier
  - Government owns/manages the data rights to interfaces
  - Protects Industry investment by allowing retention of IP to the business logic of the capability
- Designed as platform and hardware agnostic
  - Allows for unprecedented scale of reuse across multiple platforms with unique implementations
- Aggressive outreach by both Industry and Government
  - Build executive interest and adoption from the bottom up
  - 2 Contract Awards (Navy), 4 RFPs (Navy), 11 RFIs (4 Navy, 4 Army, 3 SOCOM), 2 BAAs (1 Army, 1 ONR), 4 Sources Sought (2 Navy, 2 Army) 3 SBIRs (1 Navy, 2 Army) *

* Please refer to [www.fbo.gov](http://www.fbo.gov) for the most recent list of solicitations referencing the FACE initiative

[Image]
Why a FACE Consortium?

A consortium formed under the auspices of The Open Group is a “Voluntary Consensus Standards Body” as defined by the Nat’l Tech. Transfer Act and OMB Circular A-119 with the following attributes:

- Openness
- Balance of interest
- Due process
- An appeals process
- Consensus
- Enabler for consortium participation by US agencies
- Foundation of consortium status under National Cooperative Research and Production Act (NCRPA)
The FACE Consortium was formed in 2010 by The Open Group

### Sponsor Level Member Organizations
- Naval Air Systems Command (NAVAIR)
- Boeing
- Lockheed Martin
- US Army PEO Aviation
- Rockwell Collins

### Principal Level Member Organizations
- ATK
- BAE Systems
- Bell Helicopter
- Elbit Systems of America
- General Dynamics
- Green Hills Software
- Harris Corporation
- Honeywell Aerospace
- IBM
- Northrop Grumman
- Raytheon
- Sierra Nevada Corp.
- Sikorsky Aircraft
- Textron Systems
- US Army AMRDEC
- UTC Aerospace Systems
- Wind River

### Associate Level Member Organizations
- Adacore
- Astronautics Corporation of America
- Avalex Technologies
- Avionics Interface Technologies
- Barco Federal Systems
- Brockwell Technologies
- CMC Electronics
- Cobham Aerospace Communications
- Core Avionics & Industrial Inc.
- CURTiss-Wright Defense Solutions
- DDC-I
- DornerWorks
- Draper Laboratory
- Enea Software & Services
- ENSCO Avionics
- Esterel Technologies
- Exelis Inc.
- Fairchild Controls
- GE Intelligent Platforms
- General Atomics Aeronautical Systems, Inc.
- GrammaTech, Inc.
- Howell Instruments, Inc.
- Johns Hopkins Univ. - APL
- Kaman Precision Products
- KIHomAC
- Kutta Technologies
- L-3 Communications
- LDRA Technology
- Lyn
- Mercury Systems
- Mobile Reasoning, Inc.
- Physical Optics Corp.
- Presagis USA, Inc.
- Pyrrhus Software
- QinetIQ North America
- Real-Time Innovations
- Richland Technologies
- Selex Galileo Inc.
- Stauder Technologies
- Support Systems Associates
- Symetrics Industries
- Technology Service Corporation
- Thomas Production Company
- Tresys Technology
- TTTech North America, Inc.
- Tucson Embedded Systems
- US Army Electronic Proving Ground
- Verocel
- Zodiac Data Systems

The FACE Consortium was formed in 2010 by The Open Group
Publically Available FACE Documentation

- FACE Technical Standard Edition 2.1
  - www.opengroup.org/bookstore/catalog/c137.htm
- FACE Reference Implementation Guide
  - https://www2.opengroup.org/ogsys/catalog/q142
- FACE Conformance Policy
  - https://www2.opengroup.org/ogsys/catalog/X1303
- FACE Conformance Authorities Plan
  - https://www2.opengroup.org/ogsys/catalog/X1302
- FACE Conformance Statement
- FACE Verification Statement
- FACE Conformance Verification Matrix User's Guide
  - www.opengroup.org/bookstore/catalog/x1318.htm
- FACE Conformance Verification Matrix Edition 1.1
  - www.opengroup.org/bookstore/catalog/x1318a.htm
- FACE Conformance Verification Matrix Edition 2.0
  - www.opengroup.org/bookstore/catalog/x1318b.htm
- FACE Business Guide, Version 1.1
  - http://www.opengroup.org/bookstore/catalog/q115.htm
- FACE Library Requirements Document Edition 2.0
- FACE Library Implementation Plan
FACE Objectives

- Establish a standard common operating environment to support portable capability-based applications across Department of Defense (DoD) avionics systems
  - Determine a strict set of Open Standards for the environment
  - Build upon Open Architecture (OA), Integrated Modular Avionics (IMA) and Modular Open Systems Approach (MOSA)
  - Portable, Modular, Partitioned, Scalable, Extendable, Secure
- Reduce life cycle costs and time to field
- Obtain Industry and DoD Program Management endorsement
- Facilitate conformance with standards to maximize interoperability between applications within the avionics system

http://www.opengroup.org/face
The FACE strategy is to create a software environment on the installed computing hardware of DoD aircraft (a.k.a. platforms) that enables FACE applications to be deployed on different platforms with minimal to no impact to the FACE application.
What is FACE Architecture?

- A software computing environment to enable product lines for military Aviation
- The FACE architecture is comprised of a set of “places” where variance occurs
  - Points of variance are called “Segments”
  - The structure created by connecting these segments together is the beginning of the FACE architecture
- Horizontal and vertical interfaces defined as part of FACE architecture
Eliminates Barriers to Portability

• Truly portable applications require common open standards at multiple layers in the architectures
• Prevents lock-in and improves competition throughout supply chain

• Uniform application of common open standards across DoD aviation needed to break “Cylinders of Excellence”
FACE Architectural Segments

- **FACE Portable Components Segment**
  - Portable Applications
  - Portable Common Services

- **Transport Services Segment**

- **Platform Specific Services Segment**
  - Platform Device Services
  - Platform Common Services
  - Graphics Services

- **I/O Services Segment**

- **Drivers**

- **Operating System Segment**
FACE Architecture Example - Block Diagram

Key Interfaces:
Document the interfaces that are necessary for the data converter to adapt data to and from.

FACE
Portable Components Segment
Common Services
Own Ship Position* Fusion FUEL*
Portable Applications
App1 App2

Platform Specific Services Segment
Platform Common Services
Configuration Service System Level Health Monitoring Graphics Services ARINC 739 GLX Server
Platform Device Services
GPS EGI Radar Alt

I/O Services Segment
1553 Svc 429 Svc 232 Svc

Drivers
1553 Driver ARINC 429 RS-232 Driver GPU Driver

Operating System Segment
Drivers

Transport Services Segment
Distribution Capabilities
Dist Paradigm Xilate GoS Config Capability Transformation Services
CORBA DDS ARINC/ POSIX

Framework Run-time Operating Systers OS Level Health Monitoring

Computing H/W
MIL-STD-1553 Ethernet

GPS Other Radio Radar Altimeter Cursor OFP

OFP to FACE adapter

THE OpenGroup

http://www.opengroup.org/face

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Transport Services Segment
Standardization and Constraint on UoP Interfaces

FACE components (a.k.a. FACE Units-of-Portability) are easily integrated with (i.e. "plugged into") the FACE Portable Component Segment, Transport Services Segment, and Platform Specific Services Segment due to their exclusive use of the FACE defined Interfaces.

FACE PCS Unit-of-Portability
Component supplied by Vendor “A”

FACE TSS Unit-of-Portability
Component supplied by Vendor “B”

FACE PSS Unit-of-Portability
Component supplied by Vendor “A”

FACE PSS Unit-of-Portability
Component supplied by Vendor “C”

FACE PCS, TSS, or PSS Segment

Other FACE Segments

FACE Software
FACE Data Model Architecture

- Three levels to the primary data and message models aligned with ideas from the Object Management Group’s (OMG) Model Driven Architecture™
- The addition of the Component (UoP) Model allows us to tie components to the messages and data elements in the Platform Model
- Supports definition and potentially generation of code and other artifacts
FACE Architecture - Generic Partitioned View

Standard Transport interfaces

Standard OS interfaces

Partitioned FACE Environment
Transport Services API Data Model Definition

MESSAGE DATA STRUCTURES

MESSAGE ROUTING
- MESSAGE ROUTING GUID
- MESSAGE ROUTING NAME
- MESSAGE SOURCE GUID
- MESSAGE DESTINATION GUID
- SOURCE MESSAGE DEFINITION GUID
- DESTINATION MESSAGE DEFINITION GUID

QOS DEFINITION
- QOS GUID
- QOS NAME
- QOS ATTRIBUTES (1..N)

ROUTING QOS ASSOCIATION
- QOS GUID
- QOS ATTRIBUTES VALUE (1..N)

MESSAGE INSTANCE
- MESSAGE GUID
- MESSAGE DEFINITION GUID
- MESSAGE SOURCE GUID
- MESSAGE TIMESTAMP
- MESSAGE VALIDITY
- MESSAGE DATA VALUE (1..N)

MESSAGE ASSOCIATION
- MESSAGE ASSOCIATION GUID
- MESSAGE ASSOCIATION NAME
- MESSAGE GUID 1
- MESSAGE GUID 2

MESSAGE DEFINITION
- MESSAGE DEFINITION GUID
- MESSAGE DEFINITION NAME
- DATA ELEMENT GUID (1..N)

MESSAGE DATA
- DATA ELEMENT GUID
- DATA ELEMENT NAME
- DATA ELEMENT TYPE
- DATA ELEMENT SIZE
- DATA ELEMENT UNITS

TRANSFORMATION MAP
- TRANSFORMATION MAP GUID
- TRANSFORMATION MAP NAME
- MESSAGE DEFINITION GUID 1
- MESSAGE DEFINITION GUID 2
- TRANSFORMATION GUID

DATA ELEMENT HIERARCHY
- DATA ELEMENT HIERARCHY GUID
- PARENT DATA ELEMENT TYPE GUID
- CHILD DATA ELEMENT TYPE GUID

KEY
- Required, Transmitted Message
- Optional, Transmitted Message
- Required, Configuration Information
- Optional, Configuration Information

http://www.opengroup.org/face

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Summary

✓ Introduction to FACE
✓ Introduction to TSS
• Results of RTI implementation
• Upcoming additions to FACE TSS spec
• Research Opportunities
RTI Transport Services Implementation
RTI Transport Services Implementation

DO-178C Level A Certifiable
DDS-RTPS compliant; interoperable with non-FACE DDS apps
Security Profile

Operating System Segment

Portable Component Segment

FACE Applications  Common Services

Transport Services Segment

RTI Connext™ DDS Cert

Request/Response

Publish/Subscribe

Intra- Process  Shared Memory  ARINC Ports  POSIX Sockets  Custom

Platform Specific Services Segment

I/O Services Segment
RTI Transport Services Implementation

Operating System Segment

Portable Component Segment

FACE Applications  Common Services

Transport Services Segment

RTI Connext™
Data Distribution Service (DDS)

Intra-Process  Shared Memory  ARINC Ports  POSIX Sockets  Low-bandwidth  Custom

Physical connection(s) configurable at integration time

DDS-RTPS wire protocol compliant: interoperable with non-FACE DDS apps

Publish/subscribe paradigm*

I/O Services Segment

*Will likely support additional paradigms in future
Core TSS Architecture

Built on Standard and Open Interfaces
Optimized, Location-Independent Communication

- Physical transport(s) configurable at integration time

<table>
<thead>
<tr>
<th>Transport</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intra-process</td>
<td>Within the same address space (process)</td>
</tr>
<tr>
<td>Shared memory</td>
<td>Between processes in the same partition</td>
</tr>
<tr>
<td>ARINC ports</td>
<td>Within a node; within or between partitions</td>
</tr>
<tr>
<td>Sockets (UDP unicast or multicast)</td>
<td>Within or between nodes, including over Ethernet</td>
</tr>
<tr>
<td>Low-bandwidth</td>
<td>Over satellite or radio links (no IP requirement)</td>
</tr>
<tr>
<td>Custom</td>
<td>Over custom networks or busses (via plug-in API)</td>
</tr>
</tbody>
</table>

- Applications can use multiple transports concurrently
- Transport(s) configured per application
## TSS Connection Mechanism Comparison

<table>
<thead>
<tr>
<th>Proximity</th>
<th>RTIDDS</th>
<th>Sockets</th>
<th>POSIX Queues</th>
<th>Shared memory</th>
<th>Queuing ports</th>
<th>Sampling ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intra-partition</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Inter-partition</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Inter-node</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple concurrently</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Distribution</th>
<th>RTIDDS</th>
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<th>Shared memory</th>
<th>Queuing ports</th>
<th>Sampling ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-to-one</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>One-to-many</td>
<td>●</td>
<td>●</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Many-to-one</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Many-to-many</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

● Unreliable
Deployment Example

Node

Partition

UoP
RTI TSS

UoP
RTI TSS

App
RTI TSS

Partition

UoP
RTI TSS

Partition

UoP
RTI TSS

Shared memory

ARINC Ports

Bus/Network

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rti
RTI Routing Service: Transport and Network Routing

- Component of RTI Connext Integrator
- Deployable in uncertified systems or Level E partitions
- Also supports data transformations, protocol mediation

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RTI Routing Service: Transport and Network Bridging

Node

Up to Level A Partition
- UoP
- RTI TSS

Level E Partition
- Routing Service
- ARINC Ports

Node

Level E Partition
- Routing Service
- ARINC Ports

Up to Level A Partition
- UoP
- RTI TSS

Bus/Network
Flexible Integration

Including TSS and Native DDS Apps

Airborne System

- FACE UoP
- RTI TSS
- Routing Service

Local Communication

Ground System

- DDS App
  - RTI DDS
- Routing Service

Local Communication

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DDS Natively Supports FACE Data Model

- FACE messages are now strongly typed
- OMG IDL used by FACE Platform Data Model & DDS
  - FACE messages must conform to IDL → language mapping
  - Apps can use mappings generated by RTI’s IDL compiler
- DDS natively understands data
  - Type safety
  - Heterogeneous interoperability (languages, CPUs)
  - Wire efficiency (minimizes metadata)
  - Enables middleware-level filtering (including at source)
  - Eases integration (explicit interfaces)

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Can DDS QoS be supported?

• Messaging reliability: Best Effort and Reliable
• Optional durability maintains consistent state
  – Last value(s) persisted by publisher
  – Available to late- and re-joining subscribers
  – History depth configurable on pub and sub sides
• Automatic failover: Ownership and Strength
• Send/receive cache resource configuration
Can standard tools be used with TSS?

- RTI Analyzer
- RTI Monitor
- RTI Recording Service
- RTI Excel Add-in
- Wireshark
- National Instruments LabView
- The Mathworks Simulink and MATLAB
Is there a TSS Certification Path?

- Thin layer over DDS
  - Currently <2K ELOC

- Compatible with Connext DDS Cert
  - DO-178C Level A certifiable
  - Evaluation in progress
  - ~20K Executable Lines Of Code (ELOC)
  - Small memory footprint: ~200 KB library
Summary of RTI TSS R&D results

• Proximity and physical transport independence
• Flexible communication
  – 1 → 1, 1 → many, many → 1, many → many
• Routing and federation
• Interoperability with non-FACE apps
  – Peer-to-peer with DDS apps
  – Via Connext Integrator for non-DDS apps
• Optimized support for FACE data model
• Quality of Service (QoS) can be supported
• Expeditious path to DO-178C Level A certification
• Tooling can be supported
FACE Joint Demonstration

Shows a combination of existing COTS SW and HW to provide a demonstration of the different layers of FACE

Uses a custom mediation layer within the first 653 partition
FACE Joint Demonstration

Java App

RTI Connext
DDS Micro

Android OS

ARM CPU

C App

RTI FACE Transport Service Segment
RTI Connext DDS Messaging

VxWorks 653

PowerPC CPU

DDS-RTPS Wire Interoperability Protocol

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Next Steps

• Technical
  ✓ Prototype/validate Standard Edition 2.0 (Academia)
  – Publish Reference Implementation Guidance, Edition 2.0
  – Publish FACE Technical Standard Edition 2.1
  – Develop FACE Reference Implementation Guidance, Edition 2.1
  – Develop FACE Technical Standard Edition 3.0
  – Publish FACE Shared Data Model Governance Plan
  – Release FACE Shared Data Model, Edition 2.0
FACE Technical Standard, Edition 2.1/3.0 Technical Enhancements

- FACE Edition 2.1
  - Created TSS Type Abstract interface
  - Enhanced Data Model functionality
  - Object Oriented Language Standard for TSS and I/O binding
  - Header files examples moved to the Reference Implementation Guide (RIG)

- FACE Edition 3.0
  - Updates from FACE Ed. 2.X series
  - Configuration Services update (Centralized and Local)
  - Extension of I/O Service message types
  - Extension of OS API Set
  - Extension to Multi-Core and Hypervisor
  - Data Model refinements
  - DM/TSS harmonization
  - Extension of Graphics Services
Future Research Opportunities

• FACE TSS extensibility across systems
  – i.e. TSS protocol and mediation for SoS
• Quantitative performance testing
  – Measure impact of FACE TSS on a airborne system
• Security Vulnerability assessments
• Net certification cost modeling
  – How much can we expect to save with reuse?
• Comparison to other airborne architecture standardization efforts
What is available Now

• Early Access Release (EAR)
• Based on FACE Technical Standard 2.0
• Implementation of C language TS API
• Portable source code
• No charge for TSS
• Requires license to Connext DDS edition
• Connext DDS often available free for research
Download Connext Free Trial NOW

www.rti.com/downloads
Thank you
Backup Slides
Interface Overview

• FACE Technical Standard expands on the MOSA and OA principles

• Use of abstraction layers at Key Interfaces to diminish the need for new standards
  – O/S interface (C) focused on POSIX profile 51-53 and ARINC 653
  – I/O abstraction interface (B) based on common I/O API and messaging interface
  – Standardized Transport abstraction interface (A)
    • Defined to support POSIX, ARINC 653, DDS, CORBA
    • Extensible and Flexible for integration of future transport mechanisms
Examples of Application Packaging