PRESAGIS

Understanding ARINC 661 and the benefits of 661-based development tools

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ABSTRACT

By introducing a separation between graphics and logic, an interpreted runtime architecture coupled with a defined communication protocol, the ARINC 661 Standard was designed to address many of the concerns that aircraft manufacturers faced when creating cockpit avionics displays. Before starting a project utilizing this technology, it is important to understand all of the elements introduced by the standard and to look at commercial software solutions that can streamline and facilitate the development process.

This paper will first provide an overview of ARINC 661 concepts and then describe how commercial tools can be used to simplify the creation of displays following this standard.

INTRODUCTION

The task of creating aircraft cockpit displays has grown increasingly difficult due to certification (DO-178 standard) rules becoming stricter and being applied more widely, along with the constant drive for faster time to market with lower development costs. In addition, today's Aircraft are increasingly more complex, with multiple systems from multiple suppliers all requiring a man-machine-interface with the pilot and crew.

In the late '90s, a committee of representatives from the industry was formed to address these concerns. This committee was very representative of the marketplace with members coming from aircraft manufacturers, hardware suppliers as well as software vendors such as Airbus, Boeing, Rockwell Collins and Presagis. The first version of their work was published in 2001 by ARINC under the title "Cockpit Display System Interfaces to User Systems, ARINC Specification 661" and was used to develop displays for the Airbus A380. Subsequently, five supplements were created to clarify and augment sections of the original document based on lessons learned during development of the A380 and the Boeing 787 Dreamliner. At the time of this writing, a sixth supplement is underway and should be available in the near future. ARINC 661 is also seeing uptake for the development of military aircraft as well.

From a technical perspective, the ARINC 661 Specification defines an overall architecture along with many sub-components to facilitate the creation of interactive displays. The first of these components is the Cockpit Display System (CDS), a rendering engine dedicated to presenting graphical information. Of course, a display system would not be much without its associated logic which is handled by a separate element called the User Application (UA). The link between these two pillars is the ARINC 661 Runtime Protocol, which carries events that are generated through user interaction to the UA and brings requests to display new data back to the CDS. Finally, the contents of the displays, from graphical elements to possible groupings of these components, are defined by using a finite set of components called the widget library.

This paper provides an overview of all the components listed above and continues by outlining how commercial software tools can be used to address the various parts of the ARINC 661 display creation process.

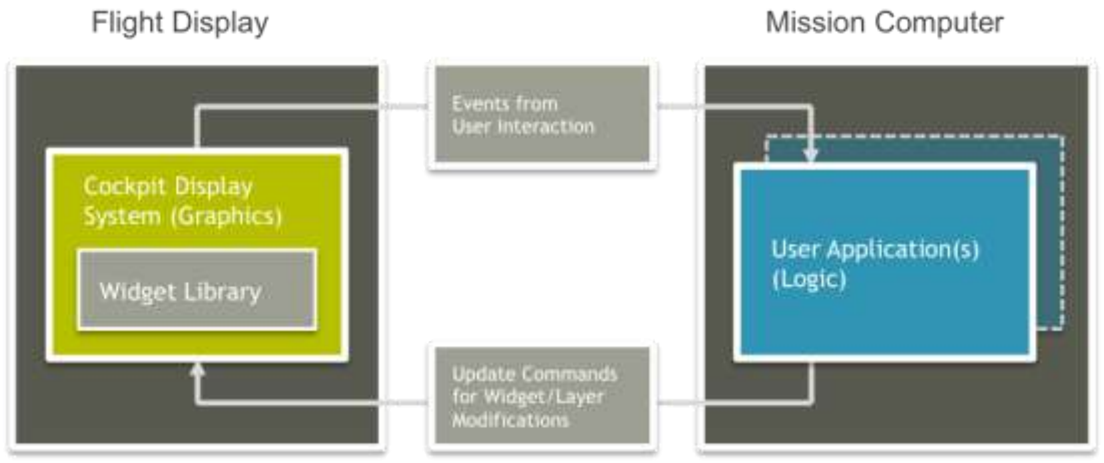
ARINC 661 STANDARD OVERVIEW

ARCHITECTURE OVERVIEW

While cockpit display software has traditionally been written as self-contained executables that present information based on internal rules and logic, ARINC 661 introduces a clear separation between the code drawing the graphics and the code managing the logic, position and state of all of the visual elements. These two components are called the Cockpit Display System (CDS) and the User Application (UA). Furthermore, ARINC 661 defines the CDS as a runtime interpreter capable of displaying one or more elements from a finite library of building blocks called widgets.

After making these two application components independent, the next step was to define a standard for them to exchange messages. Using the ARINC 661 Runtime Protocol, messages are carried from the CDS to one or more UAs when user interaction occurs. Once messages are processed, the UAs send messages back to request updates and changes to the widgets displayed by the CDS.

With all of these elements in place, the high-level system architecture of an ARINC 661-based flight display follows the diagram shown below.


Flight Display
Mission Computer
Cockpit Display System (Graphics)
Widget Library
Events from User Interaction
Update Commands for Widget/Layer Modifications
User Application(s) (Logic)

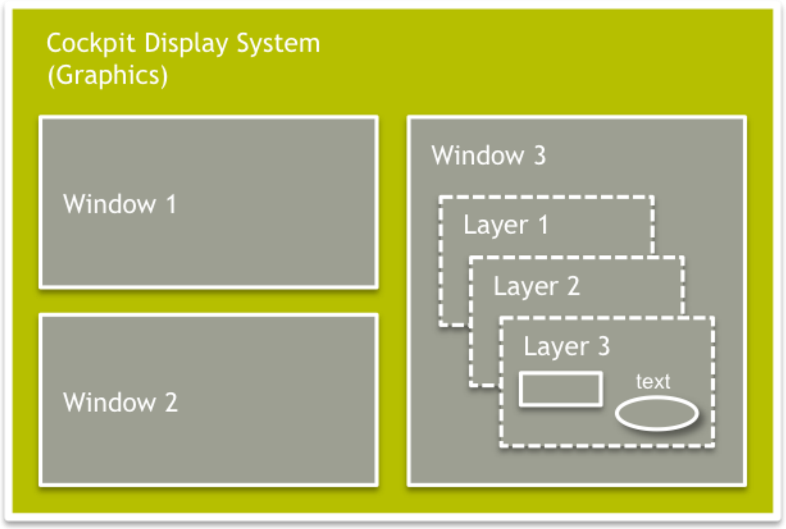
The aim of ARINC 661 is to minimise the impact on the user interface redevelopment and certification cost in response to inevitable system changes and deployment variations. In order to achieve this, all systems (UAs) need to “speak” ARINC 661 when interacting with the CDS. How UAs communicate amongst themselves is not affected.

This is a stringent requirement that necessitates that the ARINC 661 protocol is capable of supporting all of the user interface requirements of existing systems and the requirements of future systems. Major airframe manufacturers, User Application suppliers, CDS developers and ARINC 661 Tool Vendors all work together within the ARINC 661 committee to ensure that the evolving industry needs are met.

THE COCKPIT DISPLAY SYSTEM

The Cockpit Display System is responsible for displaying widgets to the end user by using a library of all the widgets defined by the ARINC 661 specification. At startup, the CDS loads and displays widgets based on one or more binary file(s) called Definition File(s) (DFs). Each Definition File contains one or more layers, which are hierarchical listings of all of the widgets that need to be loaded, once or multiple times, along with their initial properties, such as position, color and visibility.

Going down a level, the physical display attached to the CDS is divided into one or more subsections, simply called windows, which can render one or more layers. These windows cannot have any overlaps and will stack the designated layers to create the final result.



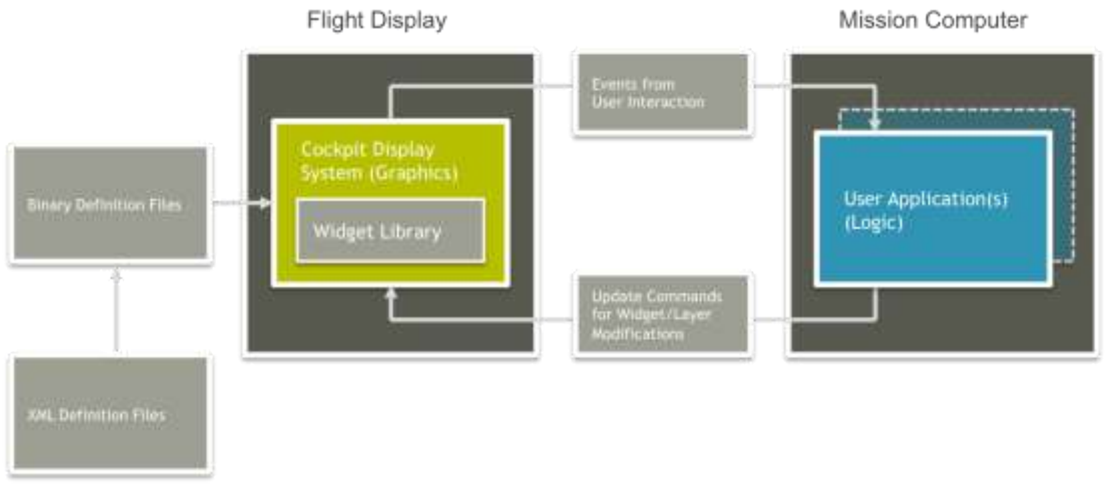
Once the CDS has completed its loading phase, all changes to the properties of the widgets are controlled by the User Application through the ARINC 661 runtime commands. During execution, the CDS is responsible for handling events that come from cursors, touch screens, keyboards or other input devices. These interactions can result in a change to the widget's visual appearance (for example, the CheckButton highlights when the cursor is located over the widget) or in the generation of an event due to a selection being made. The UA only receives these events and is not aware of specific user interactions.

There are many benefits to this runtime interpreter approach. The first of these is that the code of the CDS only needs to be written, compiled, tested and certified once. After the interpreter is finalized, updates and changes to the composition of the display are done by creating a new Definition File that will be loaded in the CDS. The same benefit applies to changes to the logic flow of the application which only results in changes to the user application.

LAYERS

Layers define groups of widgets along with their initial position and properties. All of these widgets are defined in the widget library. While widgets are given names in the definition files, it is really their designated IDs that will be used to identify them while a display is being executed inside of the CDS. This type of identification simplifies the exchange of messages between the UA and the CDS. To avoid conflicts, all widgets within a layer have distinct widget IDs. However, different widgets in different layers can have the same ID since the layer ID is also used in runtime messages to uniquely identify a widget.

Layers must be saved as binary files to be loaded inside of the CDS. However, for practical editing purposes, layers are usually stored in an XML format that is also defined in the ARINC 661 specification. Once the content creation is complete, the textual XML files are converted into binary files.


Flight Display
Mission Computer
Events from User Interaction
Cockpit Display System (Graphics)
Widget Library
Binary Definition Files
User Application(s) (Logic)
Update Commands for Widget/Layer Modifications
XML Definition Files

Besides being a simple recipient, layers also have runtime properties that can be modified such as their visibility and activation state. When a layer is invisible, all of the contents will not be seen on-screen. When a layer is inactive, none of the widgets that it contains will be selectable.

STANDARD WIDGET LIBRARY

The basic building blocks of a Definition File that will be displayed in a Cockpit Display System are simply called Widgets. The first version of the ARINC 661 Specification introduced 42 widgets that could be used to create displays. This number went up to 50 with the first update to the standard and then to its current count of almost 80 widgets with the latest revision.

Having a standard set of widgets to develop a display makes it very easy for a developer to become familiar with the ARINC 661 standard and to understand how to develop new displays. This standard set of building blocks also gives flexibility for a content developer to use CDS systems from multiple vendors as they see fit since the definition files follow a standard format. Finally, it is also possible to re-use large parts of a definition file on a new project by modifying the visual appearance of widgets to create a new CDS library.

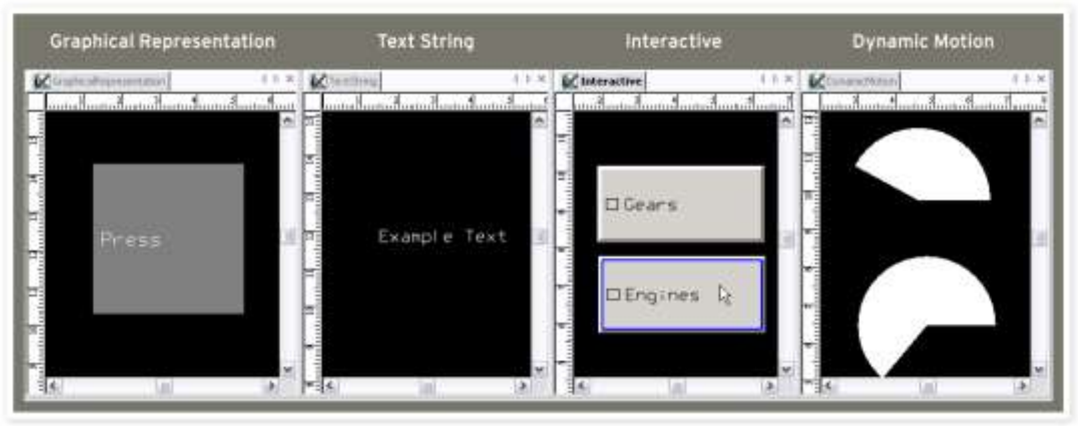
Widgets vary in complexity from basic graphical elements such as the GpLine and GpRectangle widgets to complex objects such as the MapHorz widget which displays maps from various data sources. There are also some widgets that do not have any visual representation and are used to group other elements as well as apply transformations to them. An example in this last category is the MutuallyExclusiveContainer widget that groups multiple elements but also only displays one of its immediate children at a time.

Widget Categories

In total, there are eight categories that a widget can belong to. Here is a complete list of these categories along with examples of each type:

- Container: A widget that can contain other widgets to define hierarchical organization or to provide functionality (e.g. MutuallyExclusiveContainer)
- Graphical Representation: A widget that draws graphics (e.g. PushButton)
- Text String: A widget that renders text (e.g. PushButton)
- Interactive: A widget that reacts to interaction from the user (e.g. PushButton)
- Map Management: A widget related to the rendering of a map inside of an ARINC 661 display (e.g. MapHorz)
- Dynamic Motion: A widget that can be repositioned while the display is running (e.g. GpLine)
- UA Validation: Widgets that raise events and may provide feedback whilst the UA validates the input. (E.g. ComboBox)
- Utility: Special widgets with no graphical representation, which extend functionality or provide a means to solve common technical difficulties. Examples are FocusIn, FocusOut widgets that add automatic focus change behaviour.   Also the Connector widget that enables a layer to contain child layers from other UAs.

As we can see from these examples, a widget can belong to more than one category based on its functionality.



Widget Definition

One of the primary purposes of the ARINC 661 Specification document is to provide information on all widgets. This results in two-thirds of the document being dedicated to the Widget Library.

Each widget definition in this library contains a series of standard sections that define the widget in detail. These sections are classification data, properties, Creation Structure, and Widget Description.

- Classification Data

Indicates which category(ies) a widget belongs to.

- Description

This section provides a textual description of the widget functionality. While this description gives a good general idea of the functionality of the widget, it does not provide any information on its visual appearance. This leaves the task of defining the look and feel of a widget completely up to the CDS developers.

- Special Comments

Contains high-level observations on the widget's functionality and identified relationships between multiple widgets found in the standard,

- Restrictions

Identified widgets that can only be used in special conditions or that have properties that can only be configured a specific way.

- Parameters

Besides the obvious name and definition of each property, this table also contains a column indicating whether the widget can be altered at design time, runtime, or in both modes. For most widgets, only a small number of their properties can be updated during the execution of the display. For example, if we look at a widget such as the PushButton, we can see that only four of its properties can be modified: Visibility status, Enable flag, StyleSet property and its Label text. While this type of restriction might seem like it would make displays very static, other widgets such as the TranslationContainer (a grouping widget that can move along with its children), can be used to move elements around on the display.

Besides a few exceptions, such as ColorIndex property of a GpLine, the majority of the widget properties are not used to define the appearance of a widget instance. Instead, they focus on specifying its location on the display as well as its initial settings and behavior.

- Creation Structure

This section has all of the same property names as before but goes into more technical details about them including their data types, size in bits and valid range of values. It is interesting to note that the order in which these properties are organized is not the same as the previous table. The reason behind this is a rule of the ARINC 661 specification that states that all properties must be arranged in groups totaling 32 bits, all the way to the end of the list.

This rule was created to simplify the alignment of data inside of the binary Definition Files when creating layers of widgets and to simplify memory allocation inside of the CDS. However, satisfying this need means that unused properties must be added in some cases to get the correct alignment.

- Event Structures and Runtime Modifiable Parameters

Contains a list of events that the widget can generate while the application is running and information on the messages that need to be sent to assign new values to the runtime modifiable parameters.

Style Sets

To achieve a unified look and feel across a display, ARINC 661 specifies that the look and feel of widgets is defined inside of the CDS. This means that all of the widgets of a certain type will look the same when used inside of a display. However, ARINC 661 also defines a property called the StyleSet to allow a little flexibility in configuring the appearance of objects.

The StyleSet property is a numeric field that can be used at the discretion of the CDS developers. In many implementations of ARINC 661, the StyleSet has usually been used as an index to identify one of many graphical representations of a widget that should be displayed. For example, the StyleSet of a GpLine widget could be used to select its line pattern. In other instances, developers wanting more control over the visual aspect of their widgets used the StyleSet as a long sequence of numbers, also known as a bit field, where each element has its own signification. For the GpLine widget, the same field could be used to indicate line thickness, pattern and opacity using this method.

Custom Widgets

For some projects, the set of widgets contained in the ARINC 661 standard may not be large enough to implement the desired functionality. In these cases, the standard opens up the possibility of creating custom widgets. Custom widgets will still have some common properties that all widgets have but will then be able to have a tailored list of fields to configure it at design time and to be able to send data during execution.

Custom widgets are also able to use the standard ARINC 661 runtime protocol and all other aspects of the standard.

USER APPLICATIONS

As mentioned previously, the ARINC 661 architecture introduces a separation of logic and graphics. The user application (UA) is responsible for providing data to update the contents of the CDS based on flight data and to react to user interactions with the display.

The ARINC 661 standard provides less detail on the requirements for the UA, the first statement is that a UA can be connected to one or more layers that are loaded in the CDS. The specification also specifies that communications between the CDS and the UA must use the ARINC 661 runtime protocol. Besides these two basic points, the User Application can be created using any programming language or design methodology.

The latest revision to the ARINC 661 standard, Supplement 5, Appendix 1 provides recommendations on the use of abstraction and run time architecture. An abstracted architecture will enable User Application developers to define the data that drives the user interface along with a requirement defining how the data is translated to widget outcomes. Abstraction means the UA developer is not concerned with building, optimising or scheduling ARINC 661 messages.

First and foremost, the benefit of separating graphics and logic is that a modification to the logic will not impact the certification of the CDS. This approach also facilitates the distributed development of a cockpit display across multiple teams and facilitates the simulation and testing of displays.

RUNTIME PROTOCOL DEFINITION

The ARINC 661 specification defines a bi-directional protocol that is used by the CDS and the UA to exchange data and events. The definition of this protocol is made possible by the set of standard widgets discussed earlier and the architecture put in place by the standard.

Just like the properties of the widgets, data contained in runtime protocol commands must follow a very specific order to maintain the data alignment rules specified by ARINC 661. In most cases this means creating unused variables to properly align data in memory. One interesting point concerning runtime commands is that layers and widgets are referenced using the IDs that they were assigned in the Layer definition. Therefore, all information that is transmitted inside of these messages is numeric in nature.

While the contents of data packets are very precisely defined, ARINC 661 does not mention the data transport mechanism to be used to carry messages. This allows companies to use a protocol that is either specified in the contract or with which they have the largest experience base.

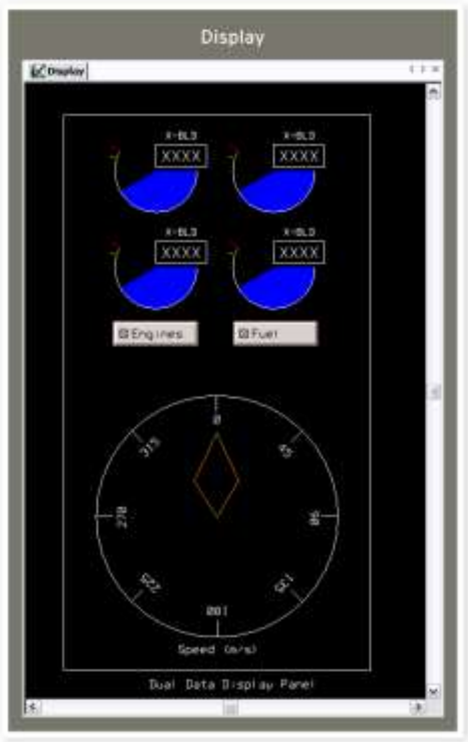
Execution flow

When a cockpit display system built using the ARINC 661 is launched, the contents of the display are first loaded from the binary definition files that are contained in the device's local storage. All of the widgets listed in the files are loaded from a library contained inside of the CDS and configured according to the properties listed.

Once all DFs are loaded, the system transitions to the Runtime Phase where the UA becomes the main controller of the contents of the CDS. The UA can send commands to request updates of the runtime-modifiable properties of widgets or to ask the CDS to modify properties of a layer such as visibility. Messages are typically only sent between the two applications when changes are needed. This results in a lower use of the processor to handle the network traffic and avoids unnecessary rendering of the display.

USING COMMERCIAL TOOLS TO ADDRESS THE STANDARD

Definition File Creation



The first concern when creating ARINC 661 displays is creating the definition files that describe the contents and layout of each layer that will be displayed in the system. While ARINC 661 clearly defines the XML format for definition files, manually editing such files is prone to human error.

ARINC 661-based development tools simplify the creation of definition files through easy-to-use interfaces and direct preview of the resulting displays. Some more concrete benefits include the ability to align and distribute graphical widgets, to easily copy one or more elements without having to manipulate XML and a direct feedback during color selection to create visually pleasing displays.

As displays are created using a development tool, definition files are usually directly stored in the XML format defined by the standard so that they can easily be converted to the binary format required by the CDS. Additional benefits of storing files in an XML format is the ability to track changes through a version control system as well as the ability to view the data in human-readable form.

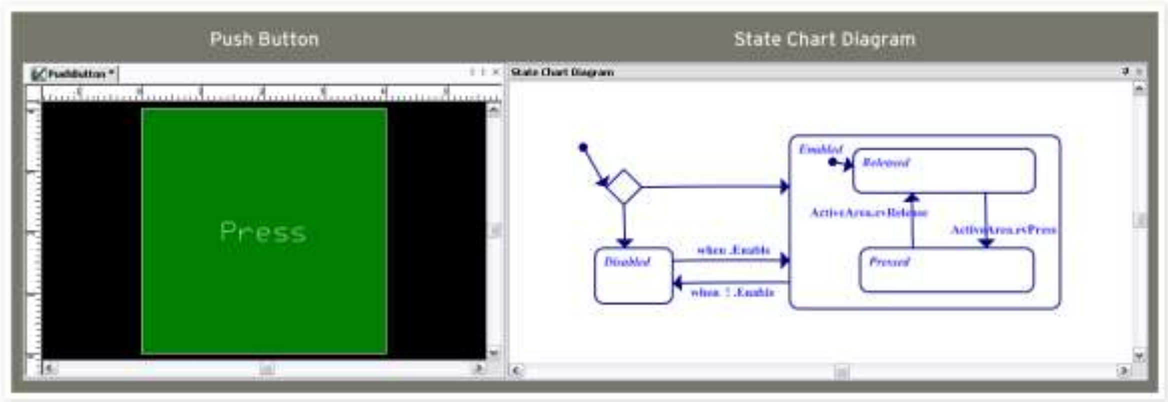
Creation of binary definition files

The natural follow-on step is the ability to convert the XML definition files to the binary format that is required by the CDS for execution. The automatic generation of binary DF files saves a lot of manual work for developers and avoids conversion errors.

Widget Library Creation

Tools supporting ARINC 661 development can also be used to develop the look and feel of a complete widget library without needing to work on the actual CDS hardware. These widgets can be created graphically, using the low-level building blocks that are provided with the tools, or through programming.

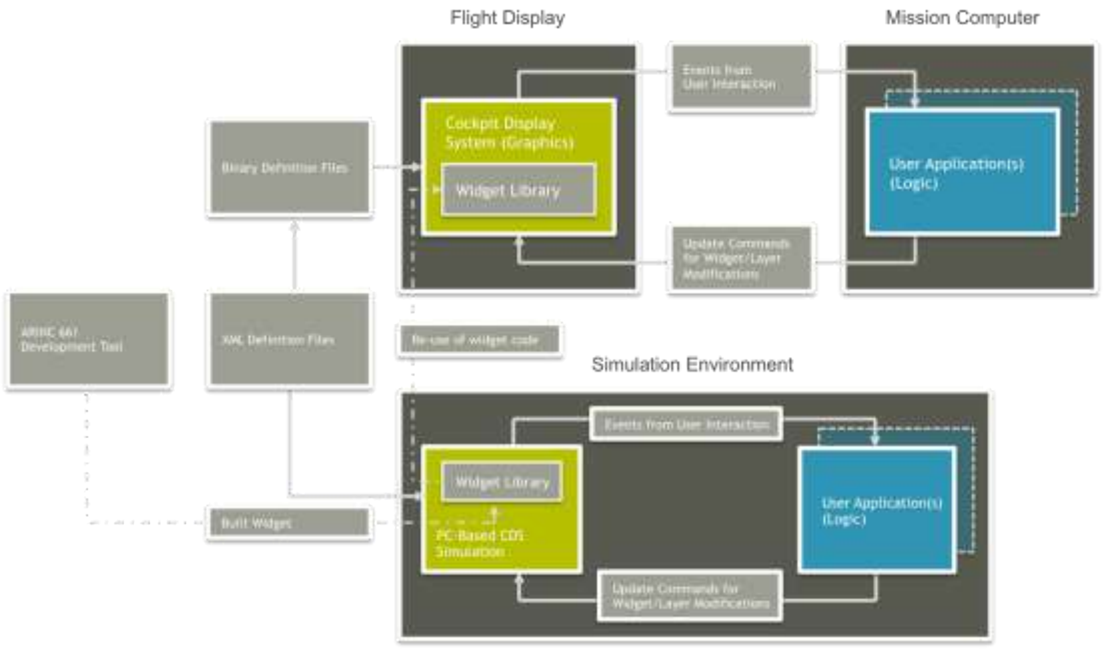
Creating widgets graphically enables quick changes to be made to their appearance during an iterative development process without needing to modify or create a single line of code. Once the graphics are defined, integrated state chart logic and data flow connections can be used to model the desired behavior.



Alternatively, widgets can be created programmatically and integrated in an ARINC 661 development tool through a plug-in architecture. While the technical knowledge required to create widgets this way is a little higher than creating built widgets, this method facilitates re-use of code between the development environment and the final CDS code. Using coded widgets also allows testing of the widget code to be done on a low-cost PC platform instead of running all of the test suites on the costly CDS hardware.

CDS Simulation

Finally, CDS vendors often focus on the creation of the CDS software that will run on their embedded solution and don't always stop to think about giving their customers or internal developers the ability to simulate their layers in a desktop environment. Windows-based commercial tools provide all of the tools to let developers get an interactive preview of their application and see the results of their selections, complete with simulation of ARINC 661 runtime protocol messages.


Flight Display
Mission Computer
Events from User Interaction
Cockpit Display System (Graphics)
Widget Library
User Application(s) (Logic)
Binary Definition Files
Update Commands for Widget/Layer Modifications
ARINC 661 Development Tool
XML Definition Files
Re-use of widget code
Simulation Environment
Events from User Interaction
Widget Library
PC-Based CDS Simulation
User Application(s) (Logic)
Built Widget
Update Commands for Widget/Layer Modifications

Embeddable CDS Kernel

The next large burden that needs to be carried by software developers is the creation of the embedded CDS software. The solution to this is to use a commercial-off-the-shelf embeddable CDS kernel.

Through a customization process, the code of the CDS kernel is able to run on any combination of hardware, operating systems and graphic libraries to render the customer’s widget library and definition files. Another related improvement is the ability to code-generate widgets constructed graphically through tools to incorporate them in this embeddable CDS framework.

Of course, an important point when using a commercial solution is to be sure that it supports the DO-178 certification standard since all of the code running in commercial airframes needs to adhere to this when used in safety-critical environments.

Document Generation

One of the most daunting tasks in display content creation is the documenting all of the work that was done. To address this, automatic document generators can take the displays created and automatically generate specifications and design documents from definition files and widgets created in the tool.

Support for new ARINC 661 features

Finally, since ARINC 661 is an evolving standard new features are constantly being added to support functionality that is introduced with each new supplement. As mentioned in the introduction, Supplement 5 was recently released and commercial CDS software development tools are continually being enhanced to keep pace with the evolution of the ARINC 661 standard.

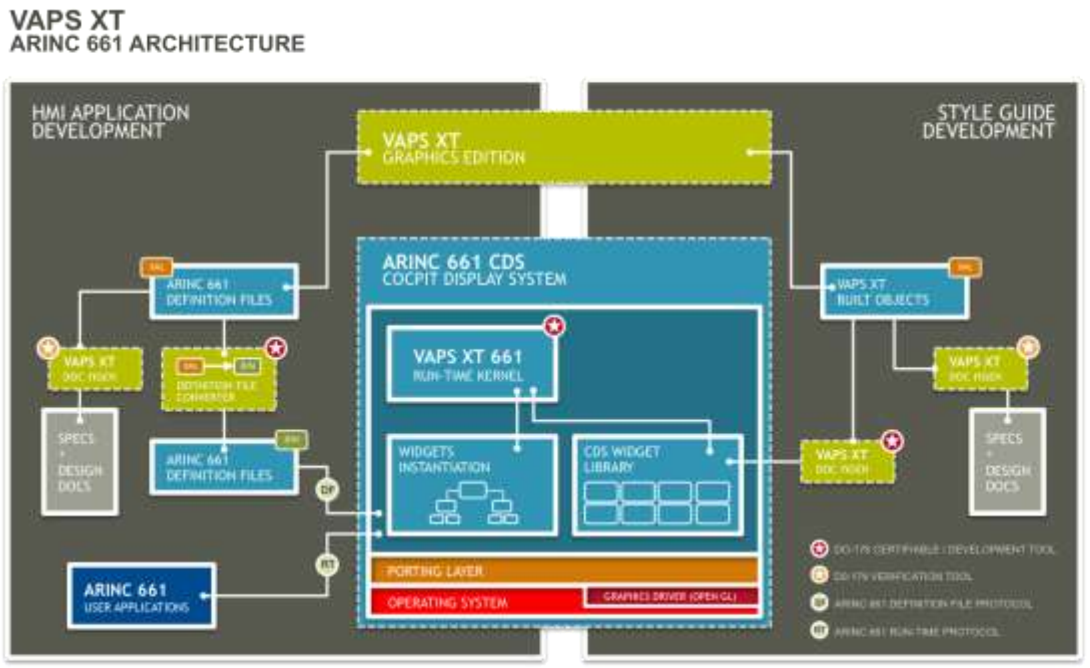
VAPS XT 661

The VAPS XT 661 tool suite from Presagis simplifies all aspects of ARINC 661 display creation. Since its introduction in 2004, it has been used to create content on multiple programs around the world.

With time, VAPS XT 661 has grown to support the entire ARINC 661 development cycle, as can be seen from the list of features:

- A full-featured graphics editor to create layers and definition files, define and simulate widgets as well as export binary DF files
- An embeddable CDS kernel that can be executed on any target through the use of a porting layer
- A code-generator to bring graphically-created contents into the embedded CDS
- A document generator to produce specifications and design documents from all of the definition files and widgets created
- A path to DO-178 certification for all code that will be running on the embedded target and for the tools used in the process

The diagram below shows how all of these components work together to provide a complete ARINC 661 development workflow.


VAPS XT
ARINC 661 ARCHITECTURE
HMI APPLICATION DEVELOPMENT
STYLE GUIDE DEVELOPMENT
VAPS XT GRAPHICS EDITION
ARINC 661 CDS COCPIT DISPLAY SYSTEM
VAPS XT 661 RUN-TIME KERNEL
WIDGETS INSTANTIATION
CDS WIDGET LIBRARY
PORTING LAYER
OPERATING SYSTEM
GRAPHICS DRIVER (OPEN GL)
ARINC 661 DEFINITION FILES
VAPS XT DOC GEN
DEFINITION FILE CONVERTER
SPECS + DESIGN DOCS
ARINC 661 DEFINITION FILES
DF
RT
ARINC 661 USER APPLICATIONS
VAPS XT BUILT OBJECTS
VAPS XT DOC GEN
VAPS XT DOC GEN
SPECS + DESIGN DOCS
DO-178 CERTIFIABLE / DEVELOPMENT TOOL
DO-178 VERIFICATION TOOL
ARINC 661 DEFINITION FILE PROTOCOL
ARINC 661 RUN-TIME PROTOCOL

SUMMARY

ARINC 661 is a very exciting technology that introduces many benefits along with an architectural design that can lower the risks of Avionics display development and certification. After the success of some large ARINC 661 based commercial aircraft development programs, many commercial and military programs are adopting ARINC 661 for their upcoming projects, ensuring the continued success of this continually evolving standard.

ABOUT PRESAGIS

Presagis is a world leader in commercial-off-the-shelf (COTS) modelling, simulation, and embedded display graphics software, and creator of the first unified COTS modelling and simulation software portfolio for the global aerospace and defence markets. As an independent, wholly-owned subsidiary of CAE, Presagis is built on a combined legacy of innovation and service, delivering superior customer value through rapid technology advancement. The company services more than 1,000 active customers worldwide, including many of the world's most respected organizations such as Boeing, Lockheed Martin, Airbus, BAE Systems and CAE.

REFERENCES AND ADDITIONAL INFORMATION

1- Wikipedia.org, ARINC 661 Dates and information
http://en.wikipedia.org/wiki/Arinc_661

2- ARINC INDUSTRY ACTIVITIES, ARINC STANDARDS
http://www.aviation-ia.com/standards/index.html

3- ARINC 661 COCKPIT DISPLAY SYSTEM INTERFACES TO USER SYSTEMS
ARINC SPECIFICATION 661-2

4- ARINC 661 COCKPIT DISPLAY SYSTEM INTERFACES TO USER SYSTEMS
ARINC SPECIFICATION 661-5