ICE Cubes

Title : Report on the ICE Cubes Ground Segment Out-of-the-Box Software

Abstract : Space Applications Services has prepared the ICE Cubes Ground Segment Out-of-the-Box (OOTB) software to be provided to the ICE Cubes customers to monitor and control their Experiment Cubes. This document reports on the developed OOTB software.

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1 Introduction

1.1 Purpose and Scope

The monitoring and control software to be provided to the customers of the ICE Cubes service is an out-of-the-box (OOTB) installable software which will allow the customers access to their experiments directly from their premises.

This document reports on the developed OOTB software.

1.2 Applicable Documents

AD1 Space Applications Services – ICE Cubes System Requirements Specification, ICU-SA-RQ-001, Version 1.4.0, 30-Jan-2017

AD2 Airbus – MPCC to IP Payloads Interface Requirements Document, ESO-IT-SPE-0025, Issue 7, 19-Aug-2016

AD3 ESA –MPCC Supported IP Protocols, ESA-ISS-COL-SEC-TN-0002, Issue 1, 09-Dec-2014

AD4 ESA – Security Requirements for LAN Connected Payloads, ESA-ISS-COL-SEC-RS-0002, Issue 1, 14-Oct-2014

AD5 Space Applications Services – ICE Cubes Ground Segment Specifications and Design Document, ICU-SA-RP-006, Version 1.1.0, 30-Jan-2017

1.3 Reference Documents

RD1 Space Applications Services – ICE Cubes Operations Concept, ICU-SA-TN-010, Version 1.1.0, 30-Jan-2017

RD2 Space Applications Services – ICE Cubes Facility Design Report, ICU-SA-RP-002, Version 1.1.0,30-Jan-2017

RD3 Space Applications Services – ICE Cubes Facility On-Board and Ground Operations Manual, ICU-SA-MA-001, Version 1.1.0, 30-Jan-2017

RD4 Airbus – MPCC Ground Node Design Document, ESO-IT-ADD-0021, Issue 1, 13-May-2016

RD5 Airbus – MPCC Phase 2 On-Board Software Design Document, ESO-IT-ADD-0019, Issue 3, 19-Aug-2016

1.4 Acronyms

AD	Applicable Document
ESA	European Space Agency
FTP	File Transfer Protocol
HDD	Hard Disk Drive
HK	Housekeeping
HTTP	Hypertext Transfer Protocol
ICE Cubes	International Commercial Experiment Cubes
ICF	ICE Cubes Facility
ICMCC	ICE Cubes Mission Control Centre
IP	Internet Protocol
ISS	International Space Station
LAN	Local Area Network
LOS	Loss of Signal
MCS	Mission Control System
MDB	Mission Database
MPCC	Multi-Purpose Computer & Communication
NTP	Network Time Protocol
OOTB	Out of the Box
OS	Operating System
PDR	Preliminary Design Review
RAM	Random-Access Memory
RD	Reference Document
RID	Review Item Discrepancy
SSD	Solid State Drive
TBC	To Be Confirmed
TC	Telecommand
TCP	Transmission Control Protocol
TM	Telemetry
U	Unit (= 10 x 10 x 10 cm)
UDP	User Datagram Protocol
UHB	User Home Base
USB	Universal Serial Bus
VPN	Virtual Private Network
WAP	Wireless Access Point

2 System Description

2.1 ICE Cubes System Overview

The main characteristics in terms of physical conceptual configuration are briefly highlighted in the following.

The ICE Cubes Facility (ICF) is composed of:

- The **Framework,** accommodating up to 20 Experiment Cubes, and providing power and data/commands connectivity.
- The structural **Container**, to be installed and mechanically fastened inside the hosting rack on board Columbus.
- **External harnesses** and **hoses** (if any), as necessary, to interface the Columbus Rack electrical jumpers and thermal control parts.
- Removable **mass memory storage devices,** namely the Solid State Drives (SSDs) and USB flash drives necessary to host the operational software and to physically download the scientific data.

The **Experiment Cubes** are standardized plug-and-play research modules (1U = 10cmx10cmx10cm) or modular combinations of that basic size.

Furthermore, the ICF allows for additional external Cubes/payloads to be either physically plugged to the front panel of the ICF or connected to the ICF LAN through the ICF WAP (private network).

A conceptual view of the ICF with the Framework and the Experiment Cubes is shown in Figure 1.

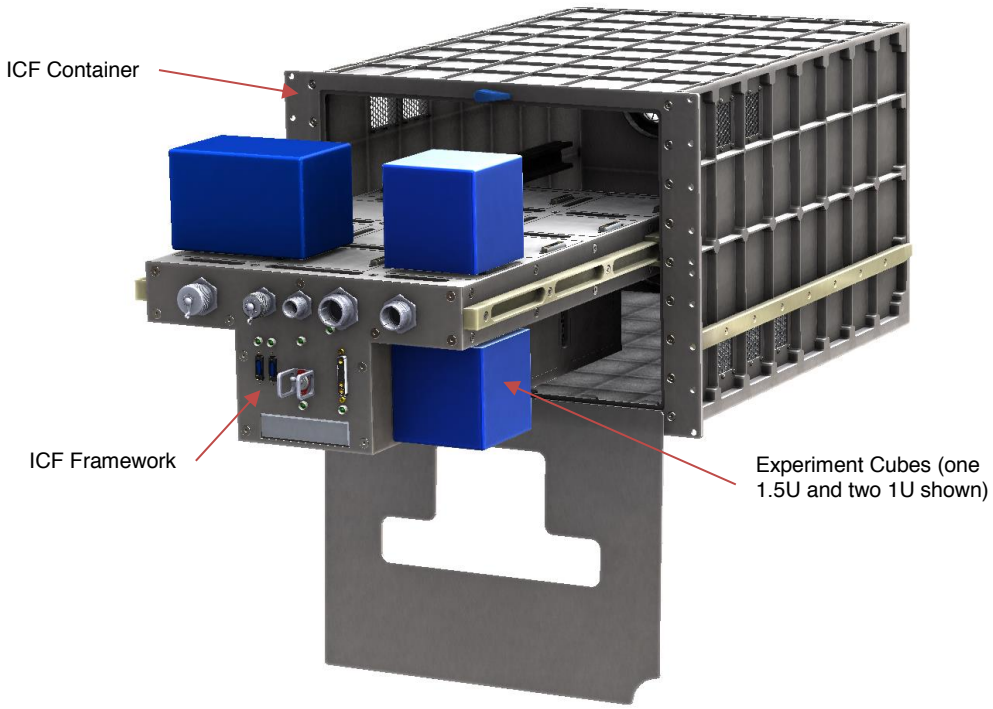

Figure 1 - ICE Cubes Facility (open view)

2.1.1 The Framework

The Framework can host a number of Experiment Cubes from the structural, power, data and thermal control points of view. The Framework is the central unit that accommodates each Experiment Cube and offers services such as connectivity and data storage.

The Framework is designed following criteria of simplicity and cross-compatibility with the various possible accommodation platforms on board the ISS. The role of providing external mechanical interfaces is left to the Container.

The Framework is powered by a single feed (10A, 28V, 280W). A LAN port is present for communication to/from ground. A dedicated telemetry line (Health & Status Data) is also present, e.g. for hardwired temperature monitoring and digital input/output to/from the hosting rack. The system, including the Experiment Cubes, is monitored and operated from ground. Nominal intervention of the crew is limited to activation of power switch, exchange of Experiment Cubes and collection of scientific data on SSD and USB flash drive, if requested.

More details about the design of the Framework can be found in RD2.

2.1.2 Experiment Cubes

The Experiment Cubes can vary per experiment but will all have to meet basic interface requirements with the Framework such as modular size, weight, interface, maximum allowable power, etc.

The size of the Experiment Cubes is set to mimic the CubeSat standard, i.e. 10x10x10cm (1 litre) for a 1U Experiment Cube, 20x10x10cm for a 2U Experiment Cube, etc. with one principal difference: the Experiment Cubes can be scaled along two axes in order to offer more flexibility to customers.

The Experiment Cubes can be functionally interconnected via the network offered by the Framework. The ICF housekeeping and the scientific data will be stored on a removable SSD and will be downlinked to ground according to the capabilities offered by the ISS infrastructure.

Different voltages / power profiles will be available for each Experiment Cube location.

2.1.3 Mechanical Configuration and On-Orbit Accommodation

The ICF will be hosted in the EPM rack, with a possibility to be transferred to EDR2, by substituting the external container, once EDR2 is installed in orbit. The design of the ICF and the relevant specifications are kept, as much as possible, cross-compatible with the accommodation in the EPM or EDR2 rack .

2.2 Ground Segment

The control/monitoring of the ICF will be performed from a ground control station (to be established by Space Application Services specifically for ICE Cubes, as baseline) minimizing the need of crew time on board the ISS.

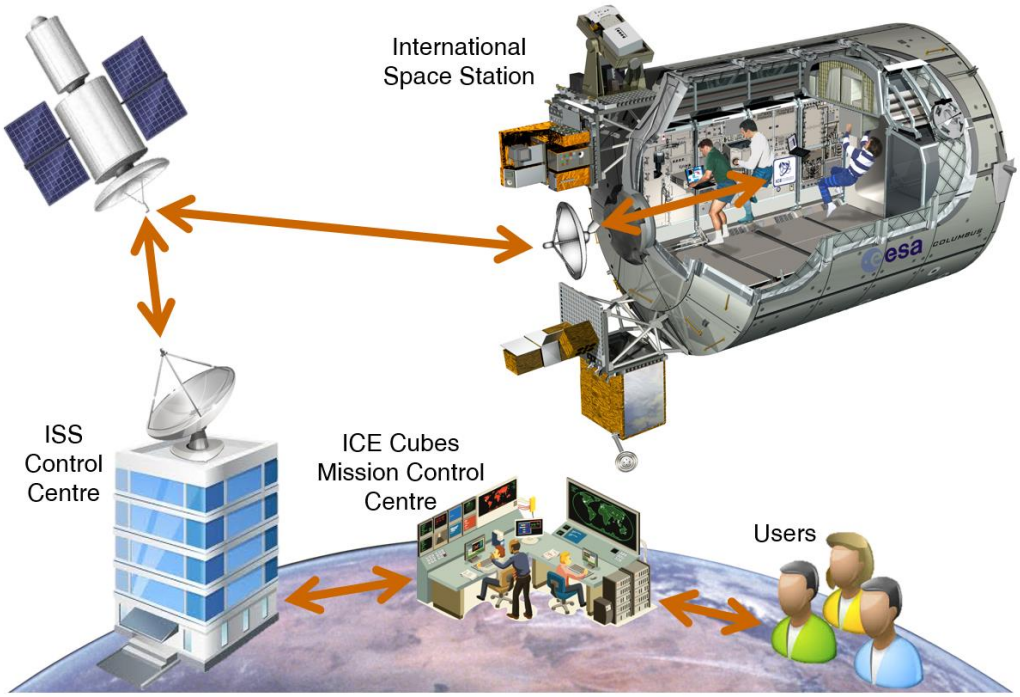

Figure 2 - ICE Cubes communications to/from ground

3 Customer Software Overview

3.1 Purpose

The purpose of the out-of-the-box (OOTB) software is to provide the customer the tools to act as a User Home Base (UHB) of the ICE Cubes Mission Control Centre (ICMCC) and therefore to access the functionalities offered by the ICMCC to the UHB to control its Experiment Cube.

The next sections describe the interfaces offered by the ICMCC to the UHBs, and the software components of the OOTB package that will allow to exploit these interfaces.

It should be noted that an Experiment Cube can be accessed via a private IP address using the generic TCP and UDP protocols. This allows the UHB to optionally use its own customized application to control its Experiment Cube additionally to the provided software package.

3.1.1 UHBs to ICMCC Interface

A UHB will use the following ICMCC services:

- VPN connection via Internet to ICMCC
- TCP connection to its Experiment Cube private IP
- UDP connection to its Experiment Cube private IP
- ICMCC NTP Service
- FTP File Service
- TCP connection for telemetry (TM) housekeeping packets
- TCP connection for telecommand (TC) packets
- HTTP server for housekeeping (HK) data
- HTTP server for planning and support

The following table lists the IP services offered by the ICMCC to a UHBs to communicate with its Experiment Cube and the impact of Loss of Signal (LOS) on the communication

Interface	Data Recoverable after LOS
TCP connection to Experiment Cube private IP	No
UDP connection to Experiment Cube private IP	No
FTP file service	Yes
TCP connection for TM housekeeping packets	Yes
TCP connection for TC packets	No

Table 1 - LOS impact on communications between a UHB and its Experiment Cube

3.2 Prerequisites

The ICE Cubes OOTB software package requisites the following minimum configuration:

- OS: Windows 7/10, Linux Ubuntu 12/Suse 11/RH 6, Mac OS 10.9
- OS: 64 bits
- Java 8 - 64 bits
- HDD capacity: 200 GB
- RAM capacity: 500 MB
- Internet connection

3.3 Out-of-the-Box Software Components

The OOTB software is composed of the following components:

- VPN client
- FTP client
- Web browser
- Mission Control System (MCS) client
- User manual

The following table lists the provided software components and the relation to the ICMCC Interfaces:

Components	ICMCC Interfaces
VPN client	- VPN connection via Internet to ICMCC
FTP client	- FTP file service
Web browser	- HTTP server for HK data - HTTP server for planning and support
MCS client	- TCP connection for TM housekeeping packets - TCP connection for TC packets

Table 2 - OOTB components to ICMCC interfaces

The following table lists the ICMCC available interfaces not covered by the out-of-the-box software:

ICMCC Interfaces	Comment
TCP connection to its Experiment Cube private IP UDP connection to its Experiment Cube private IP	TCP and UDP connections to the private IP of the Experiment Cube are dedicated to the customer custom software, and their usage is dependant of the Experiment Cube functionalities.
ICMCC NTP Service	The NTP service allows to synchronise the system time between the UHB host and the ICMCC. The UHB's OS should be configured to interface with the ICMCC NTP Service.

Table 3 - ICMCC interfaces not covered by the OOTB software

3.3.1 VPN Client

The UHB connects to the ICMCC VPN using the OpenVPN client version 2.4.3.

The OpenVPN client comes preconfigured with the connection parameters to the ICMCC.

The connection to the VPN requires two authentications factors, provided by a UHB x509 authentication certificate and a password.

3.3.2 FTP Client

The FTP client is used to uplink files to the Experiment Cube and to receive downlinked files from the Experiment Cube.

The actual synchronisation of the files between the Experiment Cube and the ground is performed by the ICMCC as described in AD5.

The FTP client is FileZilla 3.26.2.

3.3.3 Web Browser

The web browser is used to access the HTPP servers provided by the ICMCC. It allows to access the following functionalities:

- Display Experiment Cube status telemetry
- Display current planning for Experiment Cubes activation, allocated bandwidth, commanding window

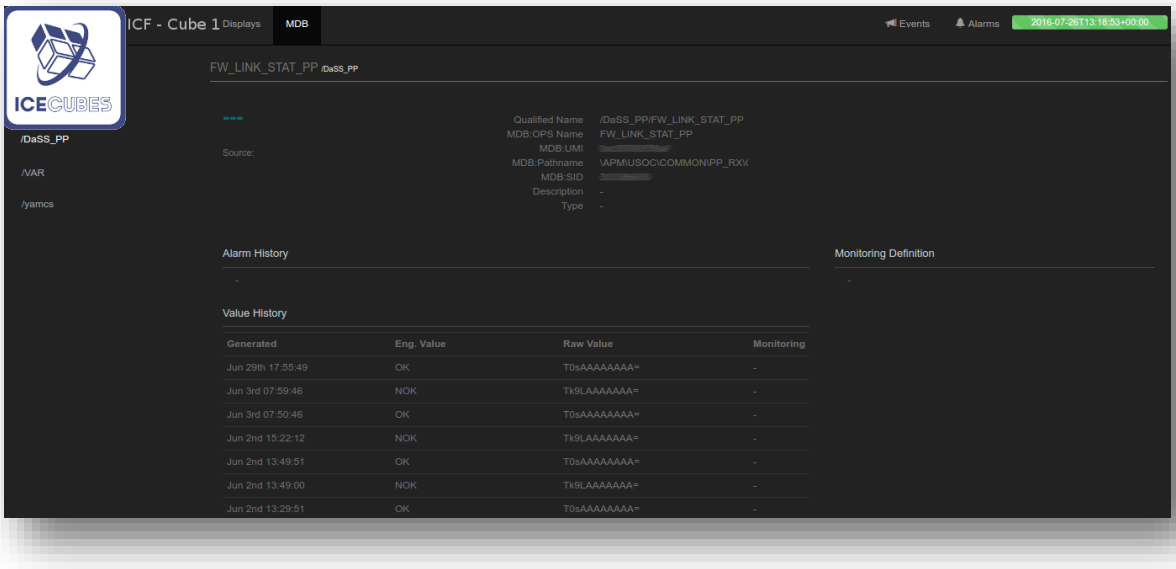

Figure 3 - Yamcs HTTP example - Experiment Cube telemetry item

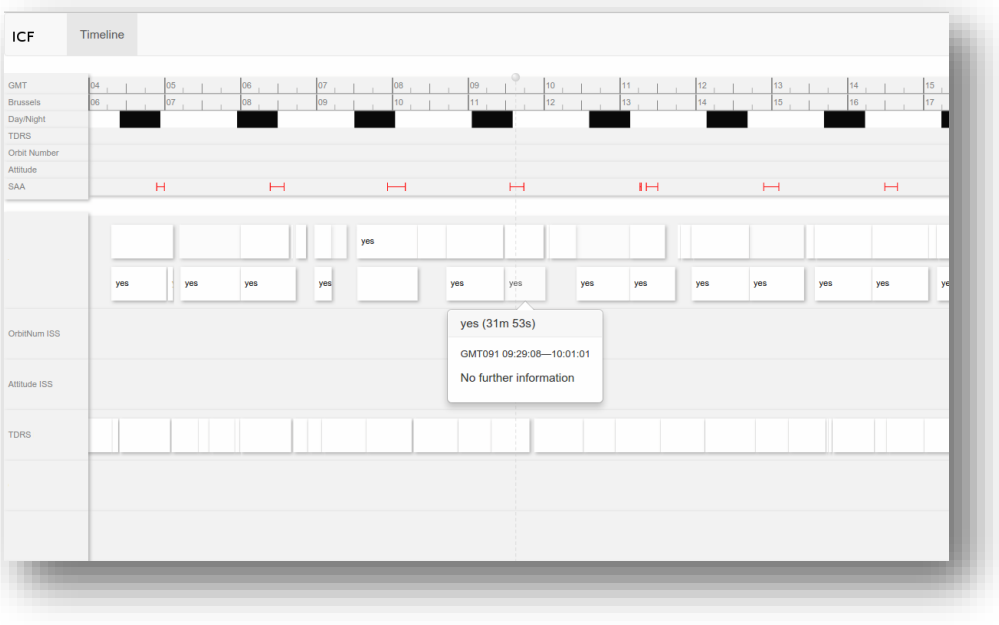

Figure 4 - Example of access to the mission planning service

The Web Browser is Firefox 54.0.1

3.3.4 MCS Client

The MCS client is Yamcs Studio.

Yamcs Studio provides the following capabilities to the UHB:

- Display of Experiment Cube TM
- Display of Experiment Cube events
- Replay requests of telemetry from the Yamcs archive
- Edition of custom displays with Mission Database (MDB) support
- Edition, import, export of telecommand manual stacks
- Execution of telecommand manual stacks
- Display of TM archive, TC history and ICF events history

The version of Yamcs Studio is Yamcs Studio B31.

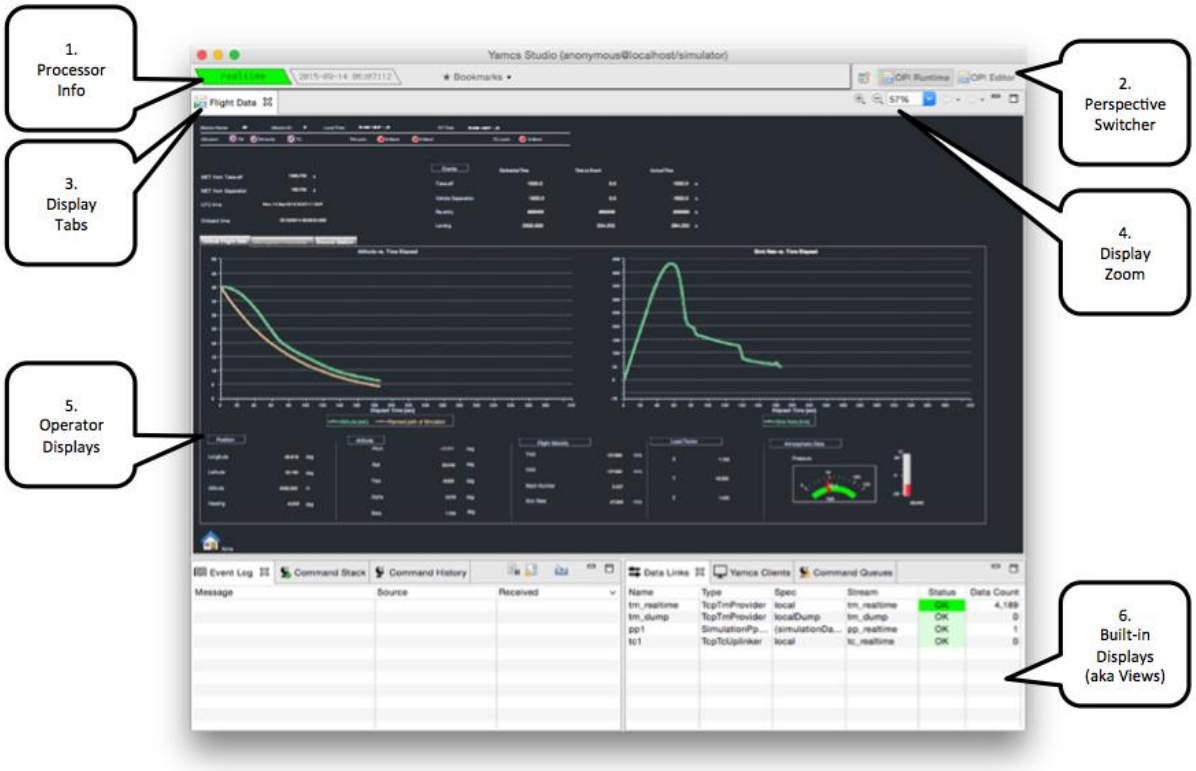

Figure 5 - Yamcs Studio telemetry display example

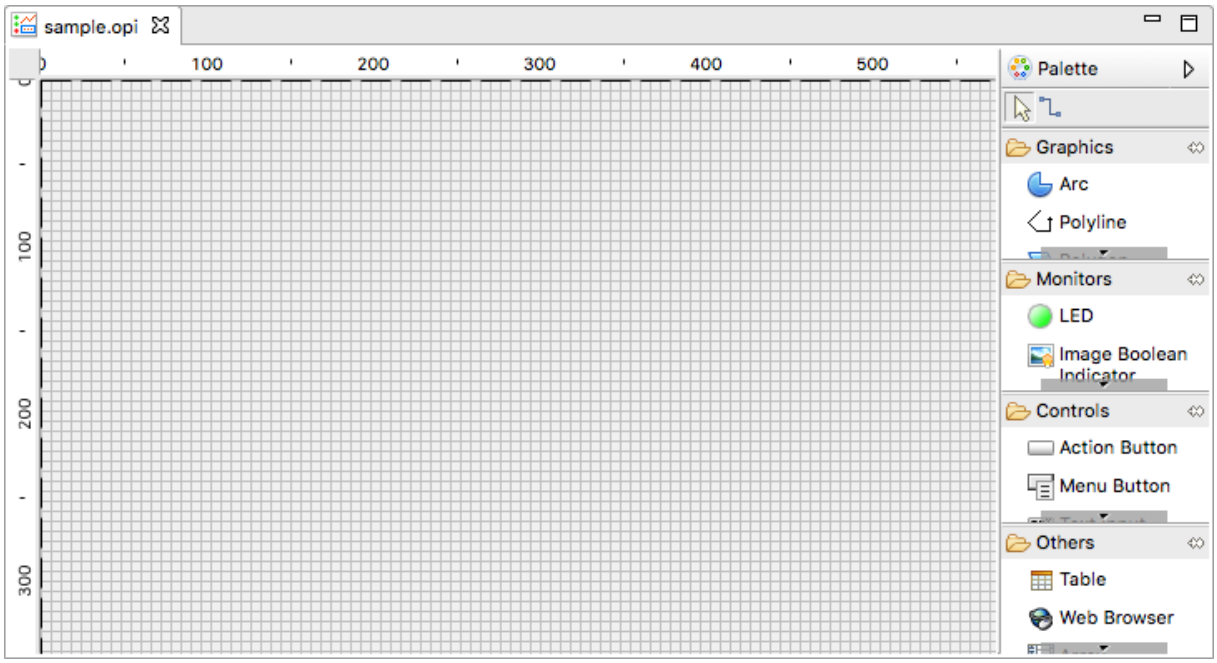

Figure 6 - Yamcs Studio display editor example

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