Vitrociset S.p.A.

The EGSE and CCV for ESA VEGA launcher

Two high complexity Systems to achieve the complete Electrical Support to the VEGA Launcher Assembly, Integration, Validation and Ground operations and launch.

VEGA EGSE

VEGA CCV

- ✓ Overview of the two system devoted to Integration and Test of Vega Launcher
- ✓ Reporting design and development experience from EGSE to CCV architecture
- ✓ Analysis of commonalities and differences

- **Background**
  - EGSE and CCV Mission
  - VEGA Launcher (overview)
  - VEGA GS (overview)
  - Schedule
- **VEGA CCV**
  - CCV ARCHITECTURE
    - CdC
    - BCVF/BCVE
    - DAS
  - CCV use and performances
- **VEGA EGSE**
  - EGSE Architecture
    - TCS
    - TES
  - EGSE use and performances
- **COMMONALITIES AND DIFFERENCES**
  - Commonalities
  - Differences

- Support the electrical operations during the Assembly, Integration and Test (AIT) phases of the VEGA launcher

- VEGA First Stage (P80) acceptance (not accepted in Industry premises by EGSE)
- Launch campaign operations, from LV integration until final countdown.

EGSE

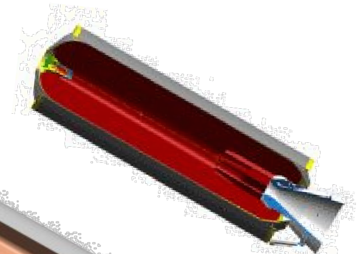
- *Acceptance tests of single stages*
- *Integration process between LV sub-systems*
- *Simulation of missing LV stages/parts*
- *HWIL (Hardware in the loop) test*

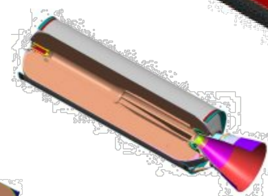
CCV

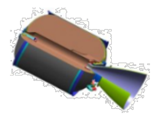
- *P80 Stage acceptance*
- *Stages Pressurization*
- *Propellant Loading*
- *Launcher Integration and checks*
- *Chronology and Countdown*

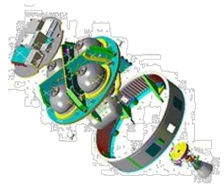
VEGA is mainly composed of 4 stages:

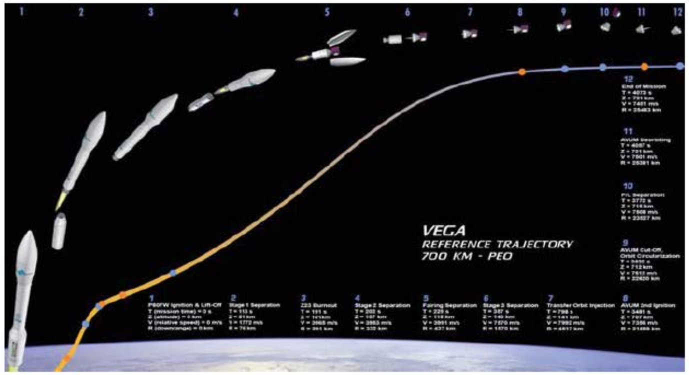
- 1st Stage: **P80** advanced technology motor
- 2nd Stage: **Zefiro 23** motor
- 3rd Stage: **Zefiro 9A** motor
- 4rd Stage: **AVUM**

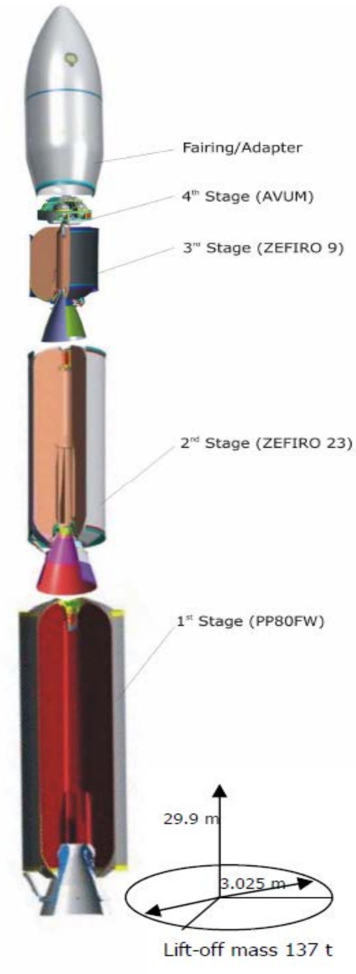












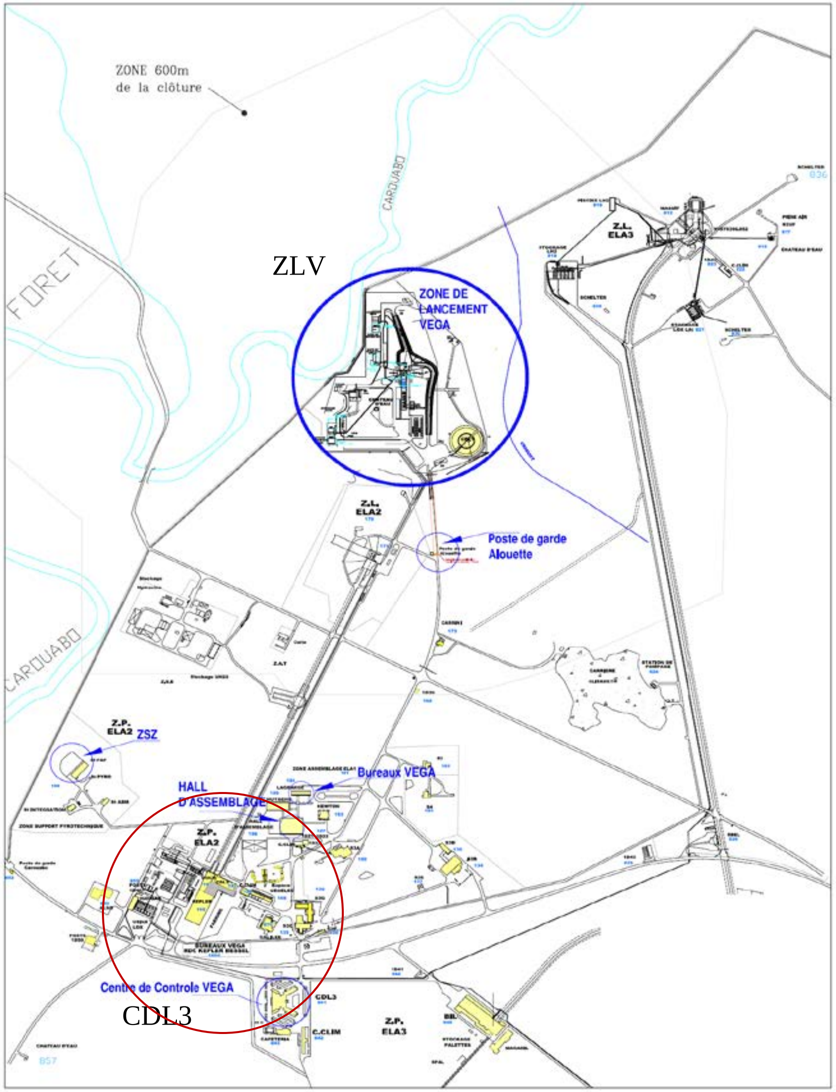
Design drivers:

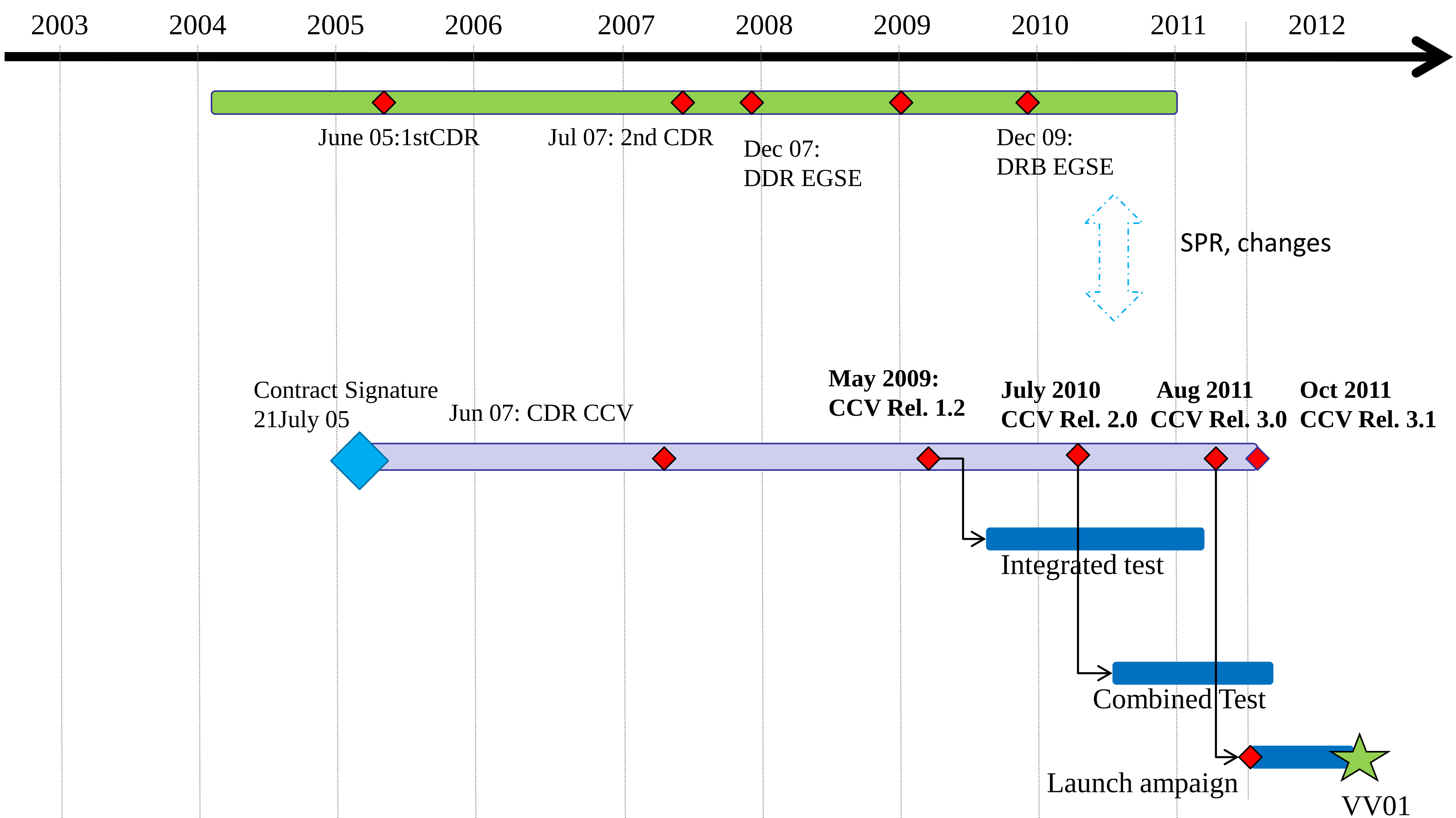
- P/L & customer comfort
- Launch Cost
- Mission flexibility
- Reliability

Height [m]	30.152
Maximum diameter [m]	3.005
Fairing diameter [m]	2.600
Mass at Lift-off [kg]	136 811
Reference mission performance [kg]	1500
Reliability	98%

The VEGA ground segment (ELV) is mainly composed of:

- ✓ The VEGA Launch Zone (ZLV), formerly ELA 1, including:
  - ❑ **Mobile Gantry** for the integration and preparation of the VEGA Launcher;
  - ❑ **Bunker** which supports the Gantry and includes the launch table and umbilical mast.
  - ❑ **Effluent Treatment Zones** (U, N, polluted waters)
  - ❑ Two independent operational control and monitoring systems:
    - o **VEGA Control Bench** (BCV) and Check-Out equipment for VEGA upper part (CCPH);
    - o **Housekeeping** control-command system (CCS) (Controle Commande Servitudes);
- ✓ Vega Control Center (CDLV) located in CDL3, including VEGA Control rooms, CdC and Data post-processing facilities.
- ✓ Lagrange Offices for Operational teams




2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
June 05:1stCDR
Jul 07: 2nd CDR
Dec 07:
DDR EGSE
Dec 09:
DRB EGSE
SPR, changes
Contract Signature
21July 05
Jun 07: CDR CCV
May 2009:
CCV Rel. 1.2
July 2010
CCV Rel. 2.0
Aug 2011
CCV Rel. 3.0
Oct 2011
CCV Rel. 3.1
Integrated test
Combined Test
Launch ampaign
VV01

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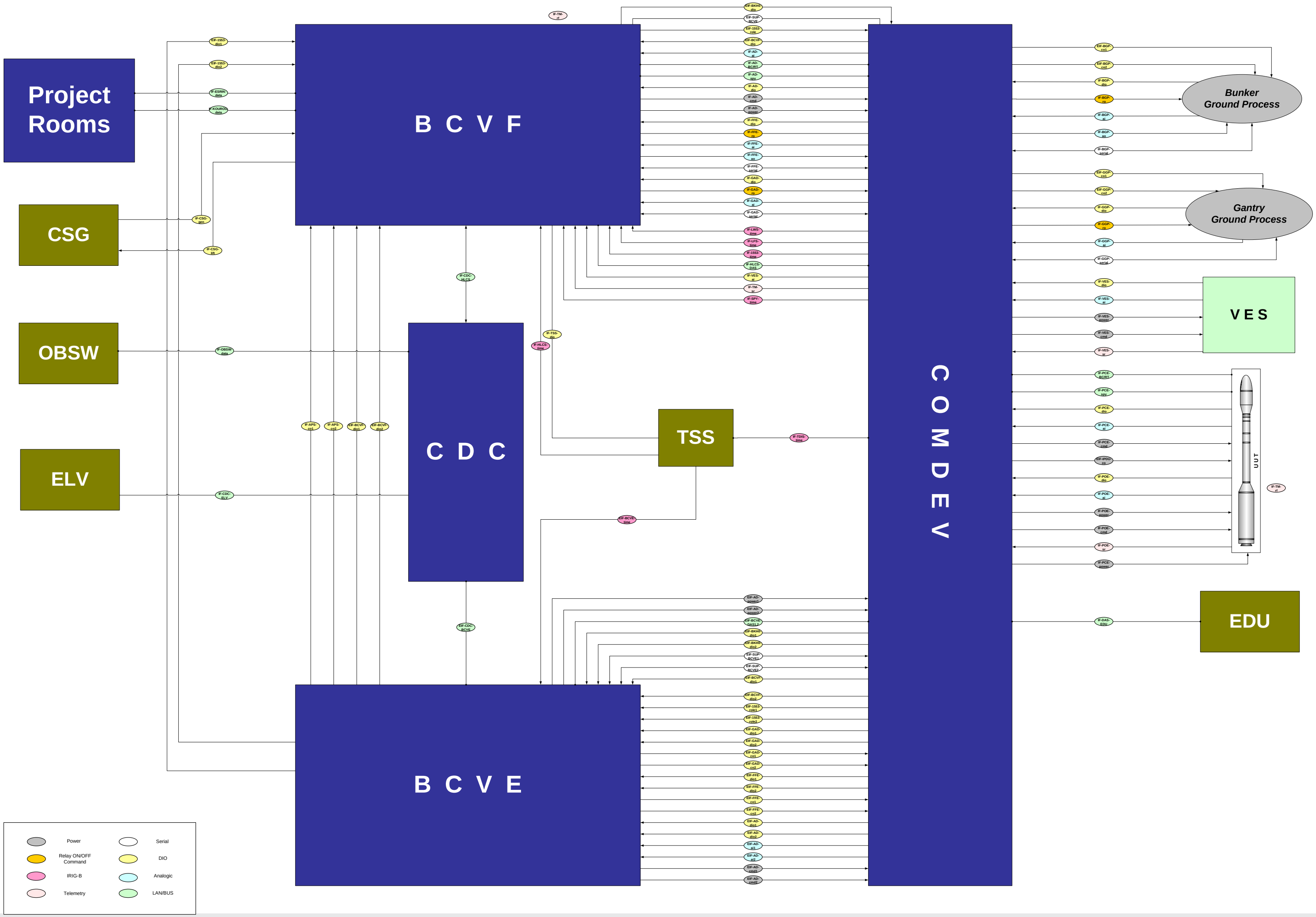

Project Rooms
CSG
OBSW
ELV
B C V F
C D C
TSS
B C V E
C O M D E V
Bunker Ground Process
Gantry Ground Process
V E S
UUT
EDU
Power
Serial
Relay ON/OFF Command
DIO
IRIG-B
Analogic
Telemetry
LAN/BUS

✓Computer Centre (CdC): performs the CCV preparation activities:

- **Automatic Procedure Development and Testing (LN3)**
- **Preparation of the Operational Configurations**
- **Maintenance of the subsystems SW (LN2)**
- **Provision of a central data repository**

✓BCVF: performs nominal operations in order to carry out the acceptance of LV first stage and launch campaign management. The BCVF architecture is composed of:

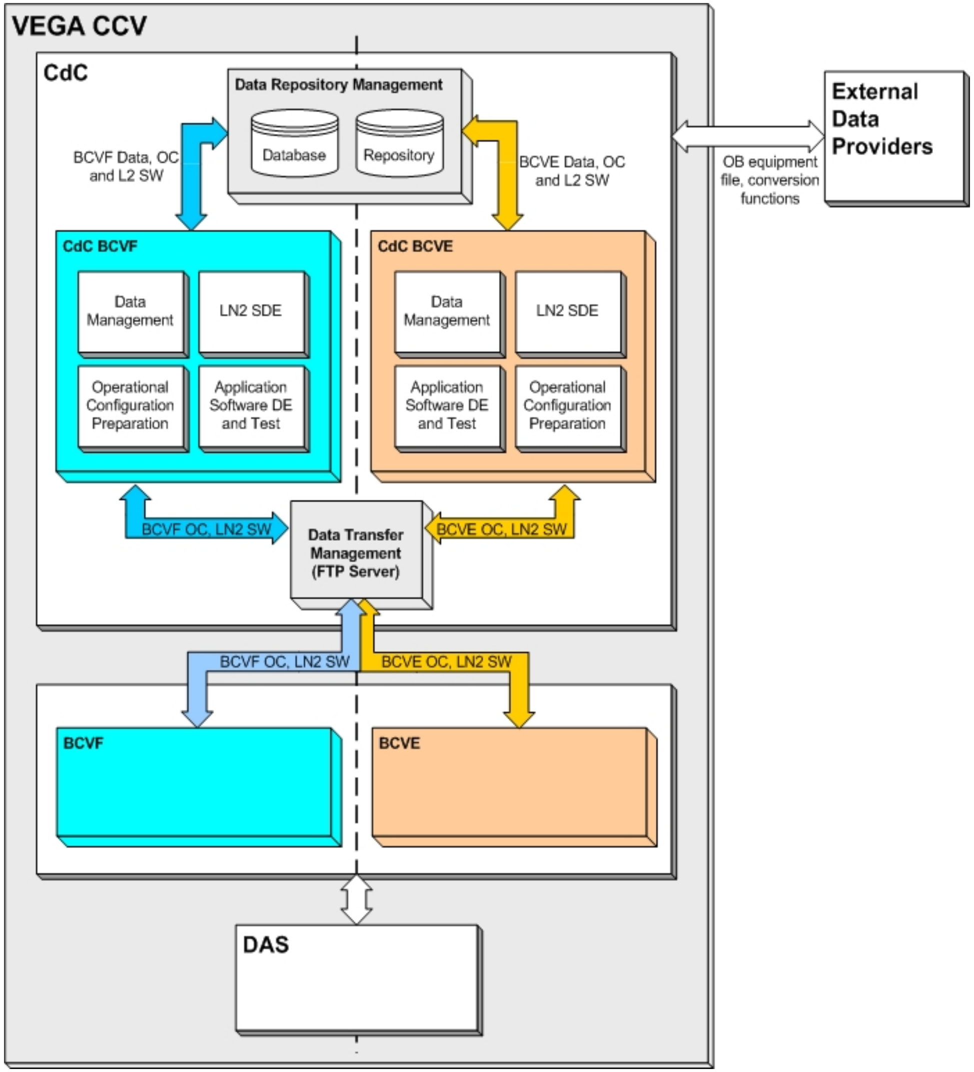
- **BCVF HLCS**
- **BCVF LLCS**

✓BCVE: devoted to put back the launcher and the ground process in safe conditions in case of BCVF failure(s). The BCVF architecture is composed of:

- **BCVE HLCS**
- **BCVE LLCS**

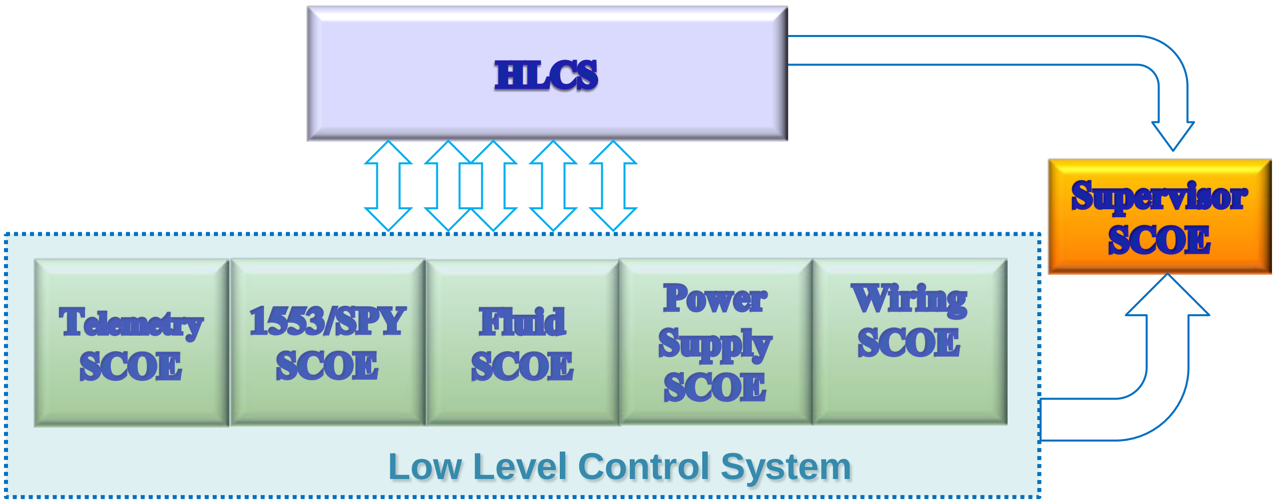
✓Common Devices (COMDEV): CCV facilities devoted to:

- **Physical interfacing with the Process/VES**
- **Time distribution in the Bunker and in the Mobile Gantry**
- **Off-Line Analysis (DAS)**

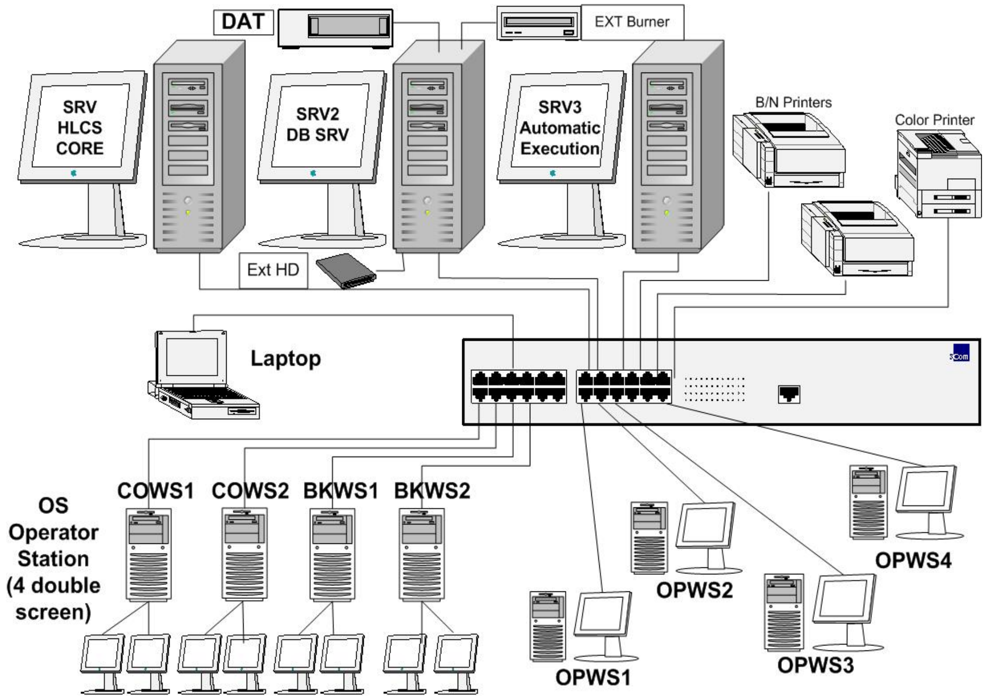


- Development and testing of application software (LN3 SW)
- Development of Synoptic displayed on the BCV
- System Database management
- Production and maintenance of configuration tables for BCV components
- Preparation, maintenance and installation of Operational Configurations (OC) to BCV.
- Maintenance of the LN2 SW running on the BCV equipments

Since the OC of the BCVE (BCVE OC) changes less frequently with respect to the OC of the BCVF (BCVF OC) the CdC is conceived to make possible the independent preparation of the two OCs. This is achieved by the physical separation of all the environments needed to prepare the BCVF and BCVE SW products.



- Capability to acquire and command through different interfaces
  - 1553
  - Telemetry
  - Hardwired
- Voltage/Current Feeding
- Archiving
- Immediate Post Processing
- Supervision

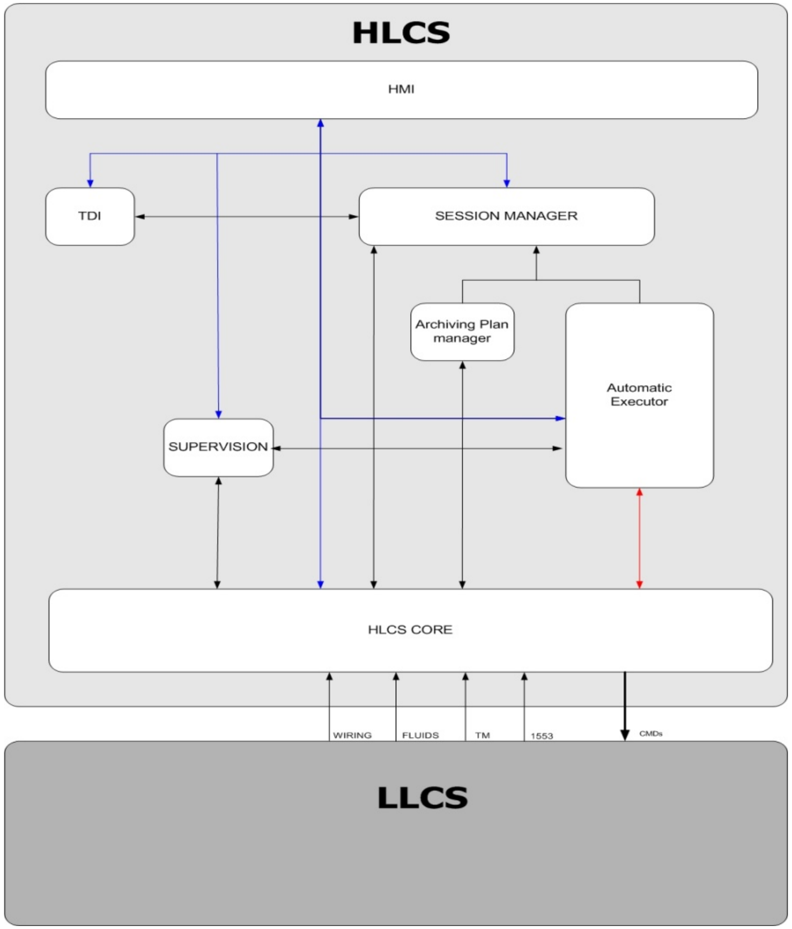


- **HLCS (H**igh **L**evel **C**ontrol **S**ystem**)** is the functional part of the CCV, responsible of conducting operations.
- Provides a set of tools to allow Operator to Monitor & Control the Launcher/Ground units (manually and automatically)
- Configures and initialize Low Level Control SCOES
- Provides Human Machine Interface
- Archives operations logs and produced results to allow analysis of the BCV behavior

CDL3 ROOM 167

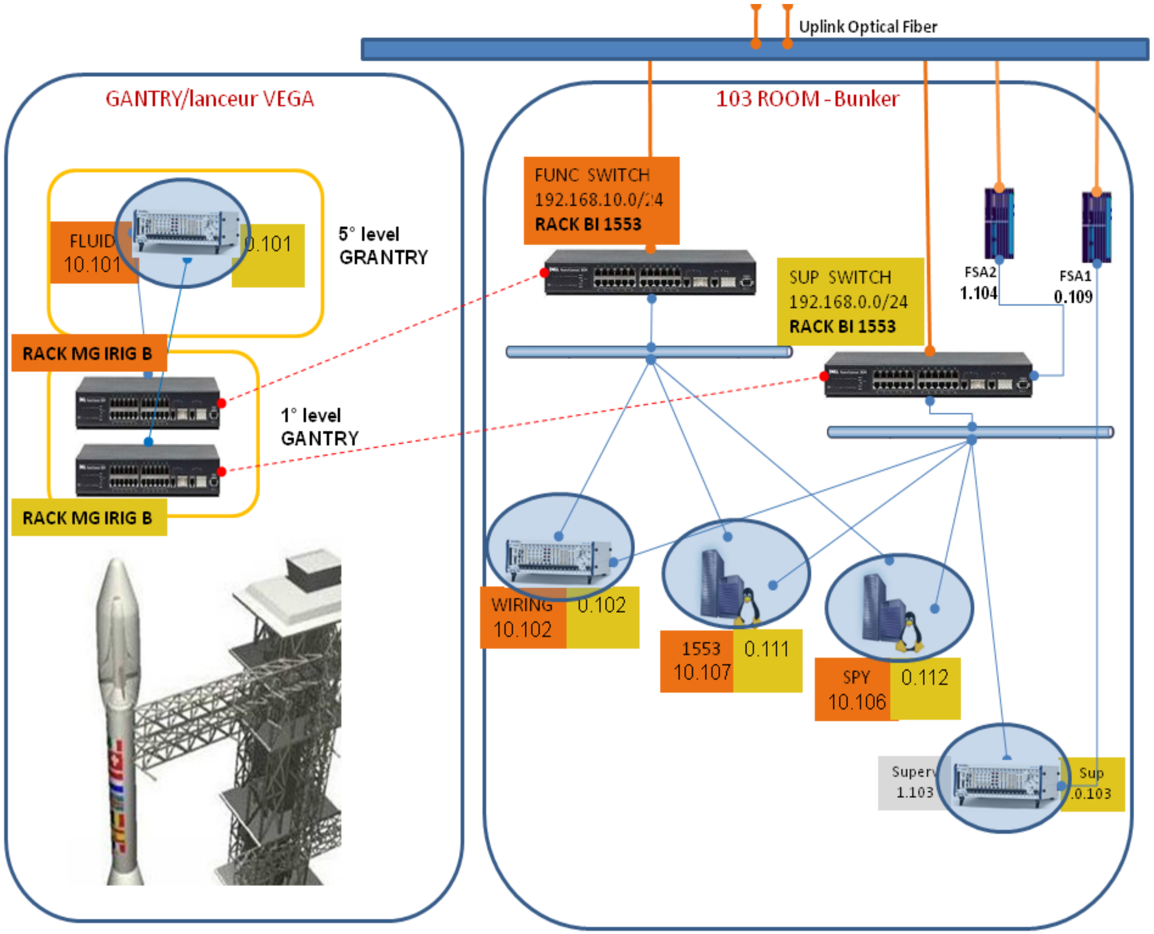
CDL3 ROOM 168

- The **HLCS CORE** main task is the management of Commanding, Monitoring, Parameters management. The other components are basically clients of HLCS core
- The **<u>HMI</u>** component is in charge to provide displays, views and GUI applications.
- The **<u>Session Manager</u>** component manages/provides:
  - Operational Configurations (OC)
  - Test sessions
  - User authentication/authorization
  - Logging system
- The **<u>Automatic Executor</u>** component provides means to execute and control PAs, part of the Level3 SW developed in the CdC.
- The **<u>TDI</u>** component allows the user to perform a large set of data analysis, over the data that is still in production by the BCV test.
- The **<u>Supervision</u>** component performs the health status monitoring of the HLCS system.
- The **<u>Archiving Plan Manager</u>** component has in charge to cyclically archive samples of LV, GP and system parameters according to archiving directives defined in Archiving Plan Files.



MAIN FUNCTIONALITIES

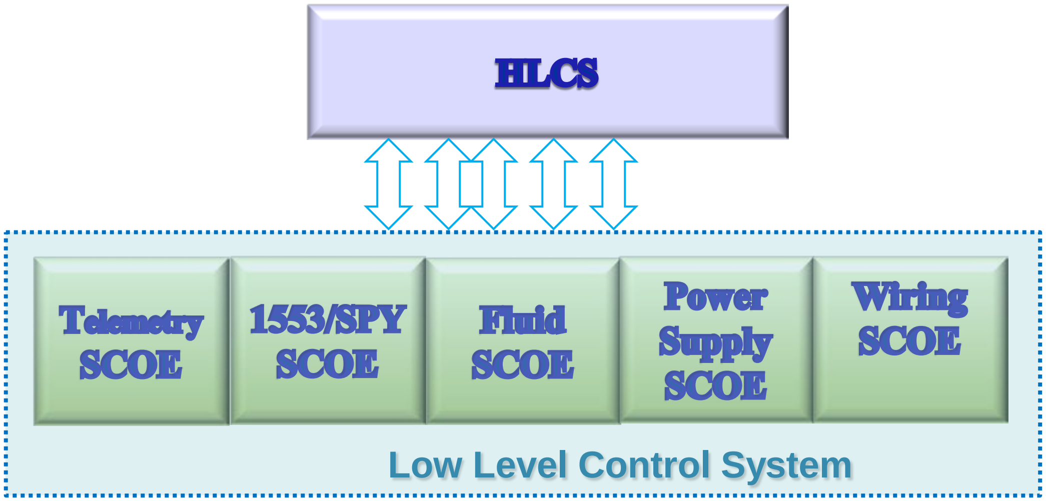
- Acquiring data from External Processes
- Calibrating and monitoring data
- Reacting in case of out of limits and anomaly conditions are verified
- Answering to HLCS requests
- Archiving acquired data and and events for post processing analysis (only 1553 and TM SCOE).



Cristina Chicarella

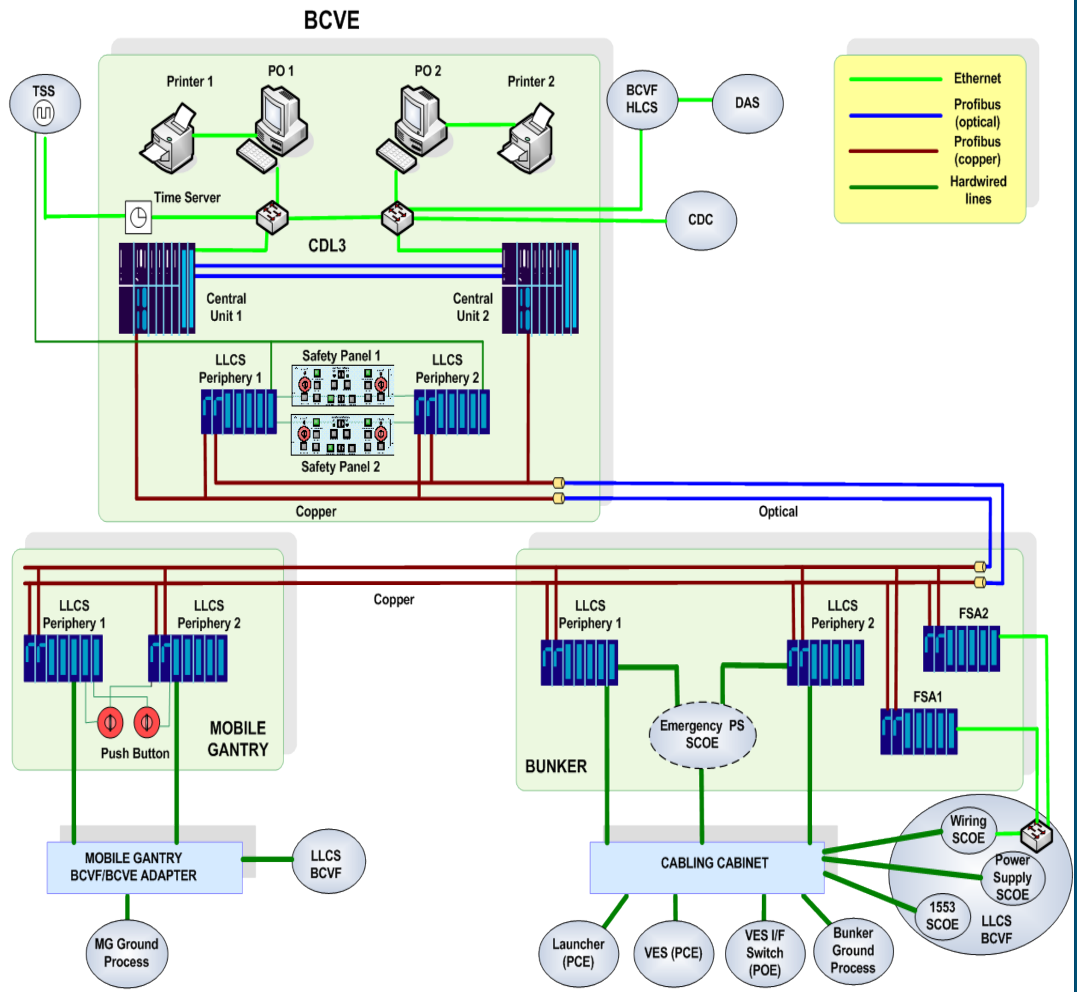
COMPONENTS

- LLCS Wiring SCOE
- LLCS Fluid SCOE
- Power Supply SCOE
- 1553 SCOE
- 1553 SPY
- TLM SCOE



Execution of two Safety Sequences devoted to put in SAFE state the VEGA Launcher and the Ground when one of the following events occur:

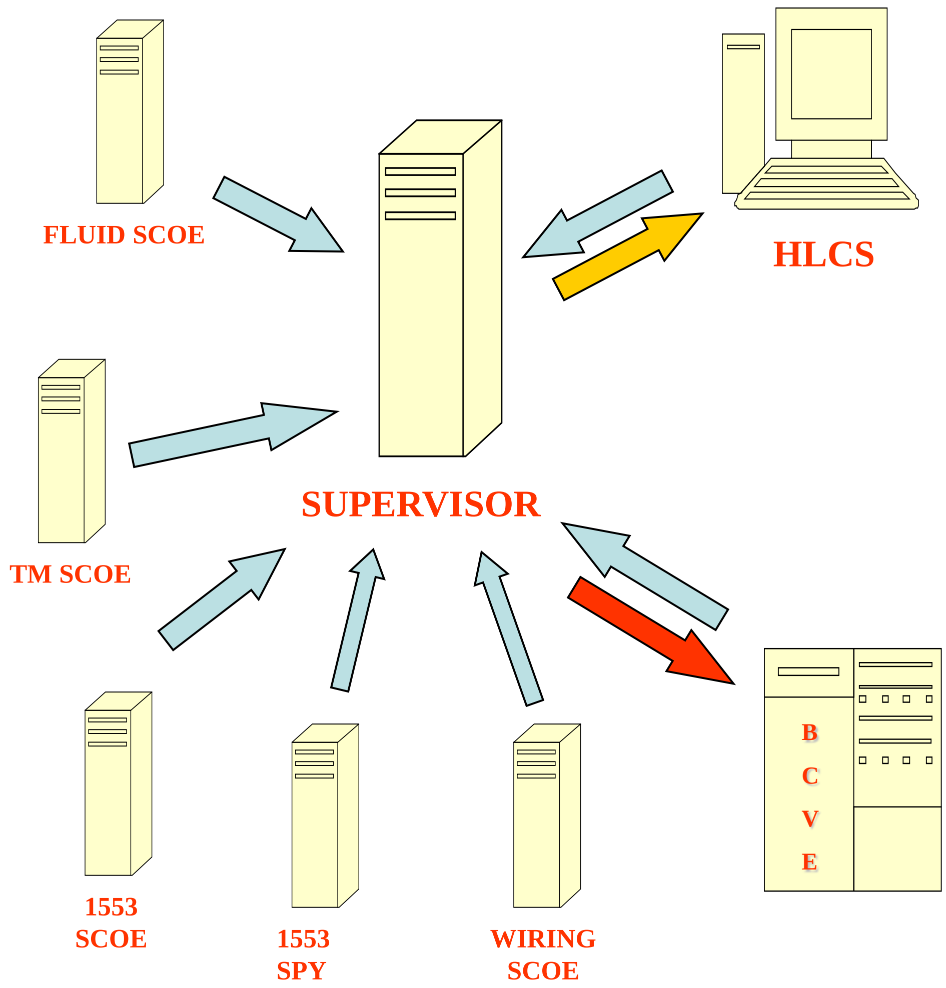
- Failure of Functional System
- Operator request (from Operator Station or Safety Panel)
- No Liftoff at H0+Tx

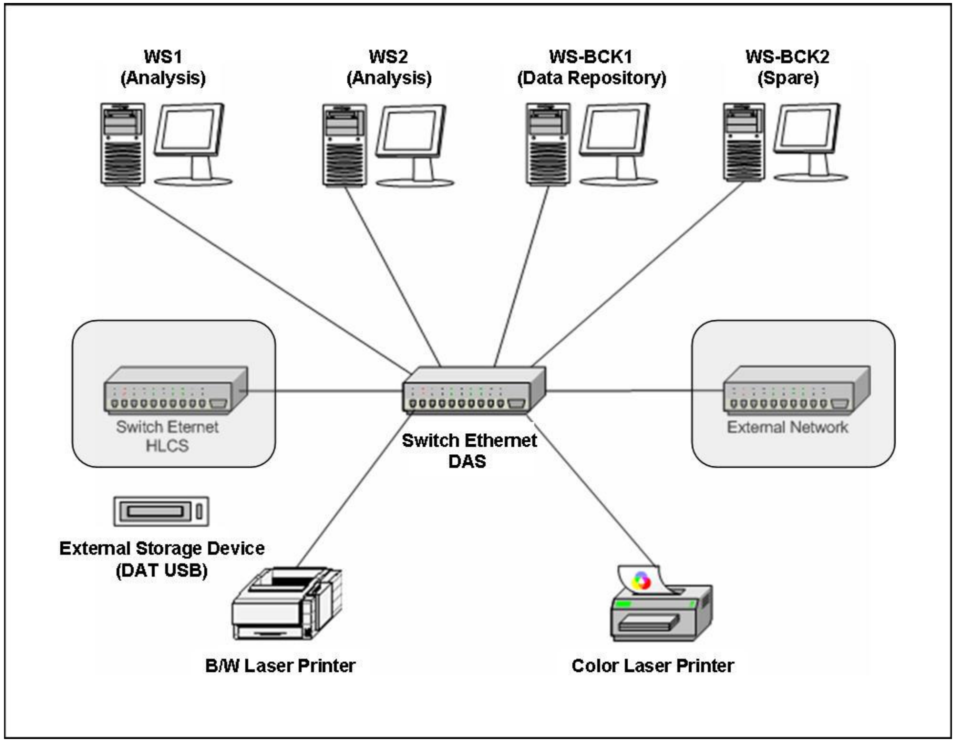


Architecture

- 2 Operator Stations in redundancy
- 2 Hot-redundant PLCs (Master/Standby) executing Safety Sequences, seen by the Operator Stations as a single PLC through the Ethernet network.
- 2 identical distributed periphery chains working in parallel constituted by several slaves (Profibus topology).
- Redundant network (coaxial and optical)
- 2 Safety Panels connected to both periphery chains
- 2 CPUs, working as Profibus slaves, in charge of the supervision of the Functional system through 2 dedicated Ethernet links

- Cyclic Acquisition of all BCVF subsystems health status
- Fatal System Alarm (FSA) elaboration
- Communication to BCVE of the occurred FSA





The Data Analysis System (DAS) is the separate CCV facility designed for the analysis of session data produced by BCVF and BCVE Applications (PA, Logs, Archiving files…)

It provides facility to plot data and create reports

The Direct Reaction function is designed considering the 1553 SCOE in BUS CONTROLLER, and foresees the execution of at least one 1553 transfer (up to 3) and, optionally, of one Hardwired LWS command.

The performance requirements are the following:

- Time to perform the DR:
  - **Less than 85ms** (mandatory for P80 Acceptance)
  - **Less than 40 ms** (desirable for Z9 and Z23 Nozzle Actuation Tests)

  This time is computed from the time the OOL is detected for a parameter received on the bus, up to when the first 1553 cmd and the LWS cmd (if requested) are sent.

- Number of 1553 parameters under DR by 1553 SCOE: **up to 10**.

Send Command Tool

-Global execution time for 1 command: **250 ms** (time included between invocation of the command tool and reception of the tool report),
- Global execution time for 10 commands (grouped commands): **500 ms**.
- For 1553 individual transfers during execution of a frame, they have to be executed during "time gaps" in the frame, namely during periods where no transfer specific to the frame is being executed.

Request flow

- Transmission flow on each interface:
- average: **4 com/s,**
- peak: **20 com/s for 2 seconds.**

Hard-wired Parameters Acquisition Tool

- Intermittent acquisition time of an hard-wired parameter: **less than 100ms** (from the time when the acquisition tool is invoked to the time when the tool report is returned),
- Acquisition time for 10 parameters (grouped): **less than 150 ms.**

1553 Parameters Acquisition Tool

- Parameter acquisition time: **less than 100ms**
- When the BCV manages the SCD, the acquisition of an SCD parameter will imply intermittent transfer on the bus (on which the parameter is present). The acquisition time is from the time of the bus transfer to the time when the tool report is returned).
- When the BCV is subscriber/observer, the acquired value will be the last value monitored on the bus (acquisition dating will always be made as close as possible to the process and available with the acquired value, making it possible to assess acquisition validity).

TM Parameters Acquisition Tool

- Parameter acquisition time: **less than 100ms** (from the time when the acquisition tool is invoked to the time when the tool report is returned). Note: the value acquired will be the last value acquired in the TM frame

Start Monitoring Tool

- Time to place one parameter under/out of monitoring **<= 100 ms**
- Time to place 10 parameters under monitoring **<= 500 ms**
- Time to place 10 parameters out of monitoring **<= 500 ms**

(monitoring execution time is from the time when the monitoring tool is invoked to the time when monitoring starts), (monitoring switching-off execution time is from the time when the monitoring switching-off tool is invoked to the time when the tool report is returned).

Stop Monitoring Tool

-Time to place one parameter under/out of monitoring **<= 100 ms**
- Time to place 10 parameters under monitoring **<= 500 ms**
- Time to place 10 parameters out of monitoring **<= 500 ms**

(monitoring execution time is from the time when the monitoring tool is invoked to the time when monitoring starts), (monitoring switching-off execution time is from the time when the monitoring switching-off tool is invoked to the time when the tool report is returned).

Parameters Monitoring reactivity

Reaction time for the monitoring function (from the moment when a limit value is exceeded to the moment when initial IT reaction occurs):

- **50 ms** for active monitoring,
- **1 s** for passive monitoring.

The reaction time for active monitoring is measured between the occurrence of the event which initiated triggering of monitoring (for example, voltage threshold exceeded) and launching of the application module activated by triggering of monitoring (ASP, MCA, etc.)

Data extracted by the HLCS log in the time window: from H0 – 7 h to H0 + 30 min

LN2 Tool	PERFO Req	Chrono Data
Start Parameters Monitoring	[PERF-SURV-020] Monitoring	count: 429; min: 3 ms max:102 ms; **avg: 28,597 ms**
Send Commands	[PERF-CMD-010] Commands	count: 166; min: 2,0001 ms; max: 53 ms; **avg: 20,078 ms**.
Parameters Group Acquisition	[PERF-ACQ-020] Intermittent hard-wired parameter acquisitions [PERF-ACQ-040] SCD parameter acquisitions [PERF-ACQ-050] TM parameter acquisitions	count: 1308; min: 0 ms; max: 89 ms; **avg: 22,359 ms**
Stop Parameters Monitoring	[PERF-SURV-020] Monitoring	count:75; min:0,99993 ms; max: 42 ms; **avg: 7,08 ms**
Start Parameters DR Monitoring	No Specific Performance Requirement for Start/Stop Direct Reaction	count: 9; min: 22 ms; max: 132 ms; **avg: 37 ms**

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  - CCV Use Cases

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  - EGSE Use cases

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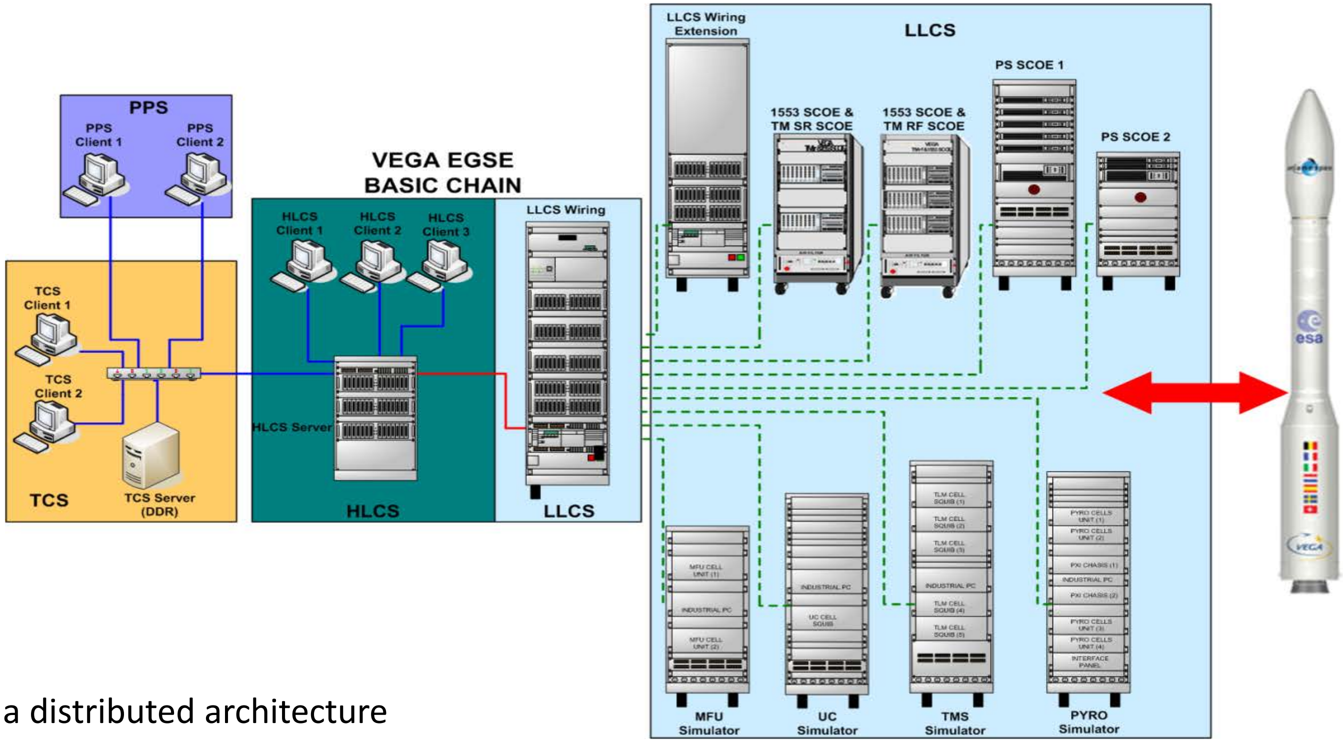
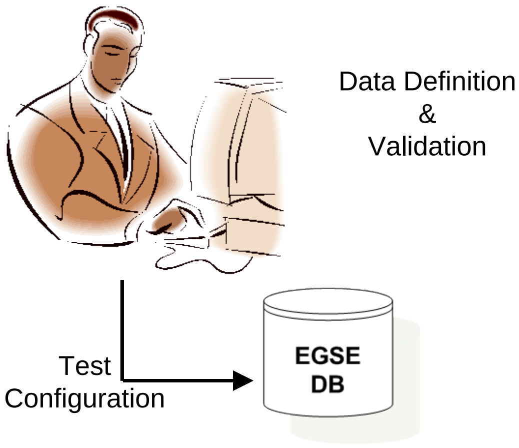


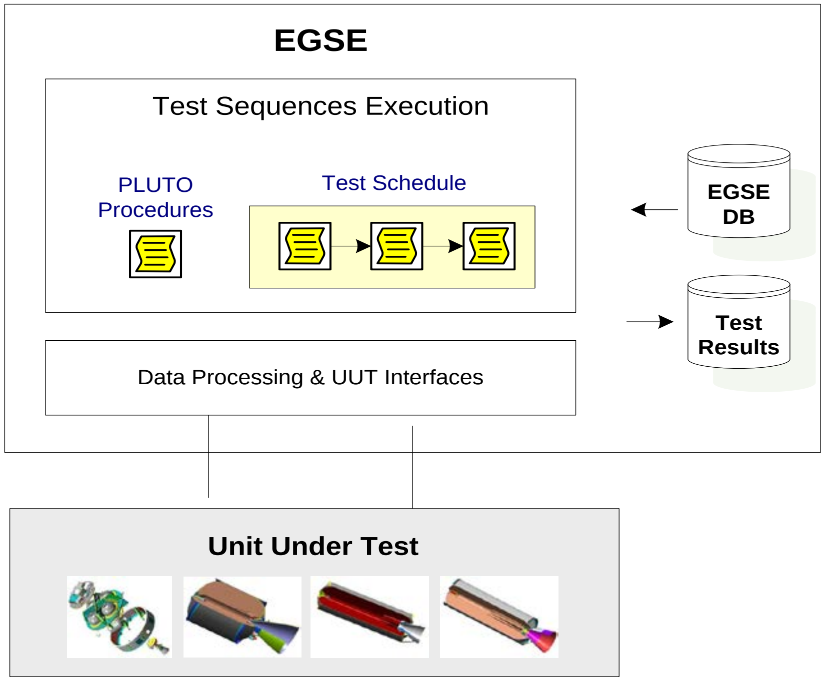
- Based on a distributed architecture
- Composed by 3 modular test chains in order to test stages of VEGA Launcher (Z9, Z23 and AVUM) in different test areas
- Each chain is composed by a basic chain + suitable composing of available SCOEs depending on the test needs
- Common TCS and PPS

Test Environment Preparation and Validation

- UUT and EGSE Modelling
- Low-level reaction items definition (e.g. parameters, commands, 1553 bus frames, etc..)
- MIB Editor: telemetry and telecommands
- Space System Model Editor: activities and reporting data
- PLUTO Test Sequences preparation and validation
- Displays definition (e.g. alpha-numeric, plotting charts, mimics)
- Consistency checking
- Session management



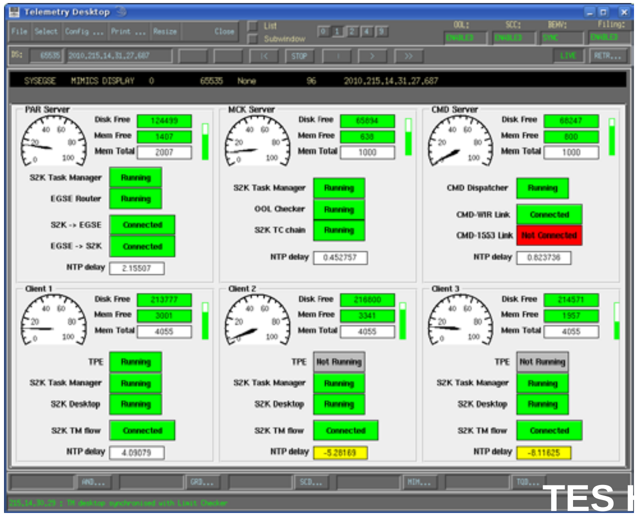
- Execution of test sequences within test sessions
- Low-Level monitoring and control of UUT elements
- Monitoring and control of EGSE elements
- Anomaly detection and automatic reaction on fault conditions within time constraints (<= 120 msec)
- Monitoring, commanding and events logging (i.e. test results generation)
- Test results reporting



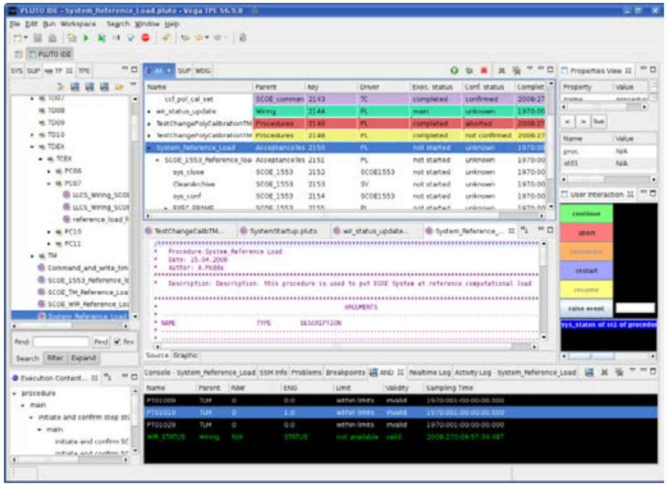
High Level Control System (HLCS) is mainly devoted to the interaction with operators and is in charge of:

- Test Sequence validation and execution
- Set of MMI and displays allowing the EGSE operator to monitor and control the EGSE and the UUT at HLCS level
- Monitoring data processing coming from specific SCOEs (i.e. LLCS Wiring, 1553 and TM front end)
- Commanding interfaces to the specific SCOEs (i.e. 1553 and TM front end) and LLCS wiring
- Logging of all performed activities
- HLCS is based on ESA SW Products: SCOS-2000 and ASE → it guarantees adherence to ESA standards

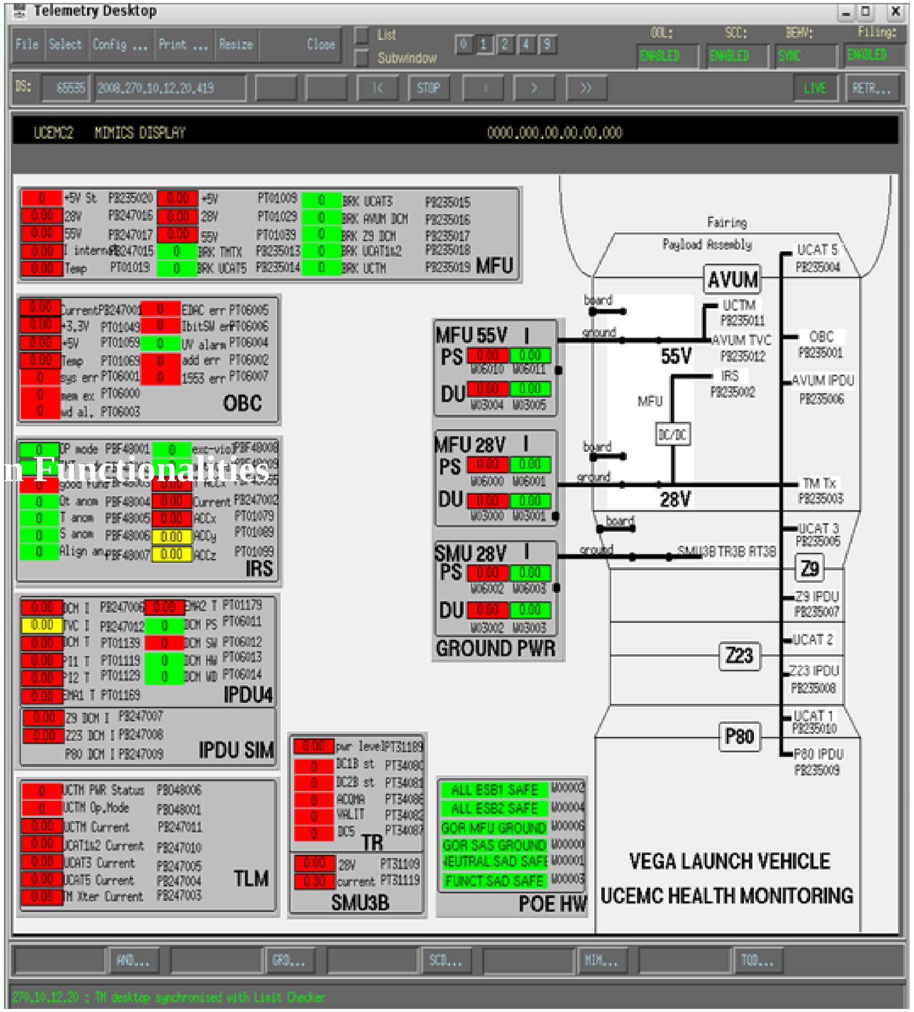
TES H... n Functionalities



SCOS 2000 Health Monitoring



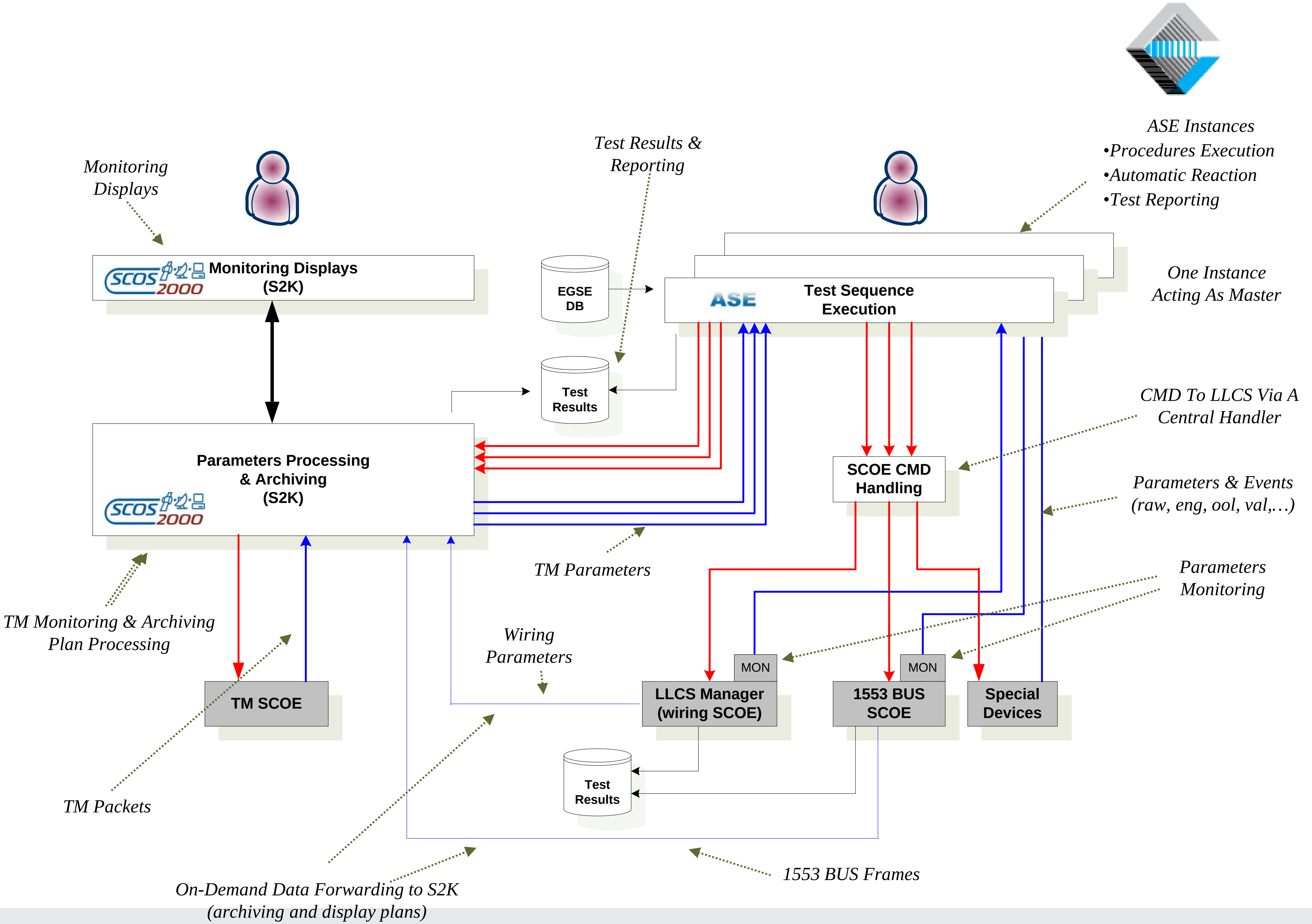
TPE User Interface



SCOS 2000 Mimics

The idea behind the design of the EGSE HLCS is the reuse of the architecture developed by ESA/ESTEC in the definition of the so called EMCS Reference Facility (where EMCS stands for EGSE and Mission Control System), making use of the full suite of components.

- ESOC MCS (SCOS 2000 r3.1) with extensions to support an EGSE protocol (to manage SCOES) and to be driven by a scripting language
- FROM ASE3 to TPE
    - Space System Model (SSM, ECSS-E70-31)
    - Procedure Language for Users in Test and Operations (PLUTO, ECSS-E70-32).


ASE Instances
•Procedures Execution
•Automatic Reaction
•Test Reporting
Monitoring Displays
Test Results & Reporting
Monitoring Displays (S2K)
EGSE DB
ASE
Test Sequence Execution
One Instance Acting As Master
Test Results
CMD To LLCS Via A Central Handler
Parameters Processing & Archiving (S2K)
SCOE CMD Handling
Parameters & Events (raw, eng, ool, val,…)
TM Parameters
Parameters Monitoring
TM Monitoring & Archiving Plan Processing
Wiring Parameters
MON
MON
TM SCOE
LLCS Manager (wiring SCOE)
1553 BUS SCOE
Special Devices
Test Results
TM Packets
1553 BUS Frames
On-Demand Data Forwarding to S2K (archiving and display plans)

Acquiring data from UUT;

Calibrating and monitoring data;

Reacting in case of out of limits and anomaly conditions are verified;

Answering to HLCS requests;

Storing all acquired data and logging all activities and events for post processing analysis.

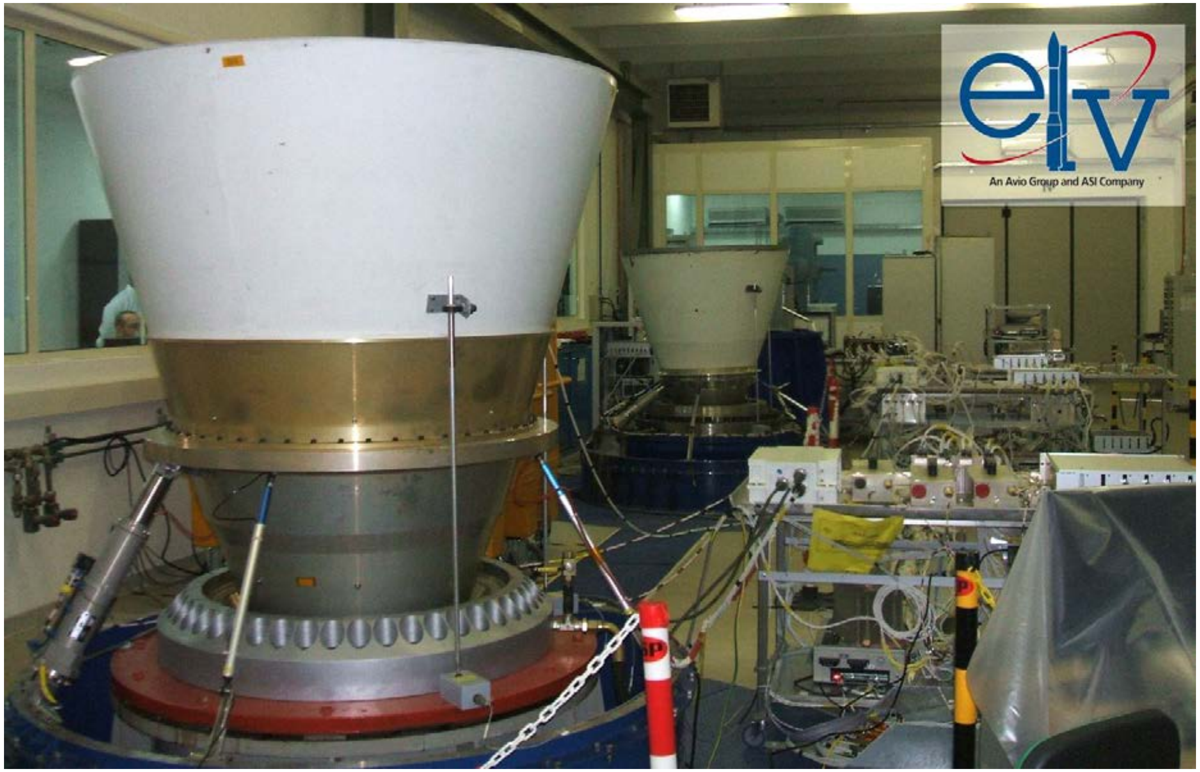
- LLCS Wiring SCOE
- Power Supply SCOE
- 1553 SCOE
- TLM SCOE
- Pyro Simulators
- MFU load Simulator
- Upper Composite Sim
- Telemetry Sensor Sim

LLCS VEGA-EGSE Chain 2

Hardware in The Loop (HWIL) Campaign

Validation of:

- Overall Avionics System
- Integration Procedures
- Avionic Operation (SMO)



HWIL Test Setup

VEGA Subsystem Validation

Assy A2 Acceptance

Assy Validation Campaign

TVC Swiveling test & telemetry sensors acquisition and validation.

SAS Campaign

The LV safe system is validated trough the avionics stimulation. Neutralization and Functions Commands provided by EGSE.

ELIF Campaign

VEGA equipment electrical interfaces validation

Telemetry Campaign

Avionics telemetry system Validation

P80 TVC swivelling

Reaction loop mechanism	Reaction loop description	Reaction times	CCV Performance characterization
Fast Reaction Loop at LLCS Wiring SCOE level	OOL Condition detected by LLCS Wiring SCOE on Hardwired parameters and reaction executed by LLCS Wiring SCOE through Hardwired commands	30ms/40ms	6 ms→28 ms HW commands 13-23 ms 1553 transfer
Fast Reaction Loop at 1553 SCOE level	OOL Condition detected by 1553 SCOE on 1553 parameters and reaction executed by 1553 SCOE through 1553 commands	30ms/40ms	Not implemented
Reaction 1553- LLCS Wiring SCOE	OOL Condition detected by 1553 SCOE on 1553 parameters and reaction executed by LLCS Wiring SCOE through Hardwired commands	65ms/85ms	Not implemented
Reaction Loop 1553-TPE-LLCS Wiring SCOE	OOL Condition detected by 1553 SCOE on 1553 parameters, event sent to TPE, which requests the LLCS Wiring SCOE to send Hardwired commands	120ms/140ms	<20 ms for sending request
Reaction Loop 1553-SCOS-TPE	OOL Condition detected by SCOS on 1553 parameters, event sent to TPE, which requests the LLCS Wiring SCOE to send Hardwired commands	150ms/170ms	Not implemented

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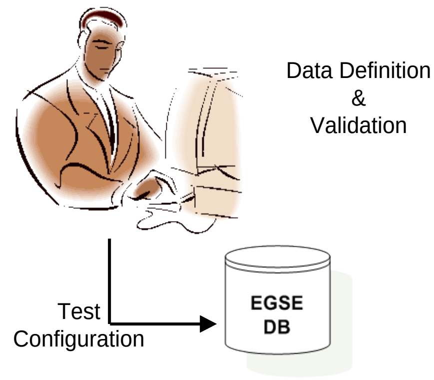
  - Differences

Environment Preparation and Validation (EGSE TCS, CCV CDC)



Low-level configuration items definition (e.g. parameters, commands, 1553 bus frames, etc..)

Operational Sequences preparation and validation

Displays definition (e.g. alpha-numeric, plotting charts, mimics)

Consistency checking

Operation Execution
(EGSE TES, CCV BCVF)

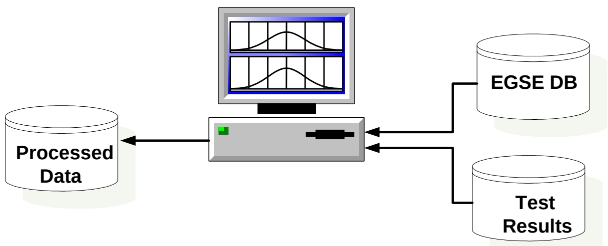
Execution of Operational sequences within campaign

Monitoring and control of external equipment s

Anomaly detection and automatic reaction on fault conditions

Data Storage

Test results reporting



Post Processing Operation Execution
(EGSE PPS, CCV DAS)

Import of Configuration Data and stored data collection

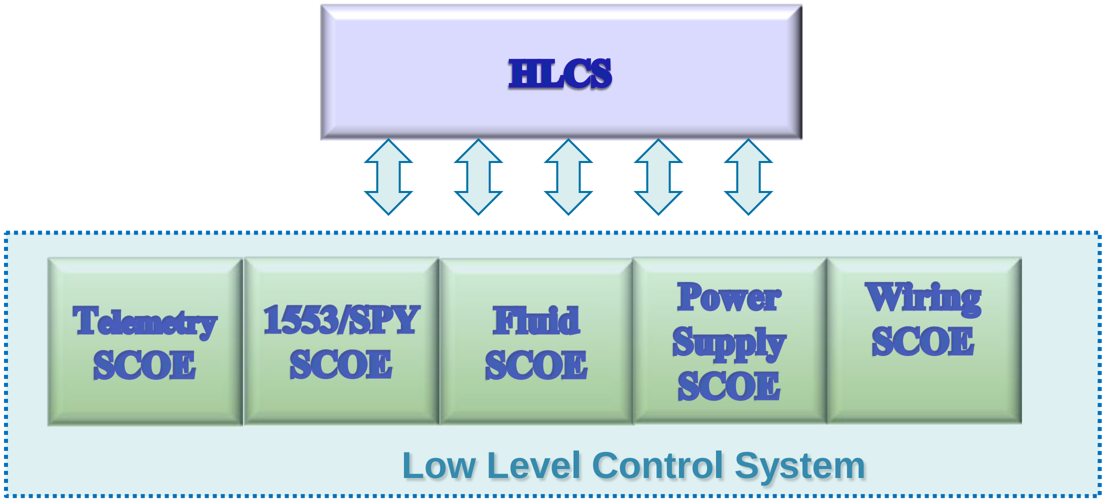
Data treatment: Analysis and processing

Data display and reporting

Data Filtering

TES and BCVF commonalities

- common breakdown of the Tests/Operations Environment: composed by an High level System (HLCS) providing manual and automatic human interfaces capability and centralizing the management of the Tests/Operations and a LLCS that is composed by several SCOEs, each one interfacing with the Launcher by a different interface technology.



- LLCS components are based on the same technologies
- Same HW and SW, same providers, same COTS

SCOE	HW technology	SW	OS
Wiring, FLUID	PXI, SCXI NI board	Labview	Pharlap
1553 SCOE, SPY	Aim 1553 Board	C,C++	Linux
TM SCOE	Custom Board	C,C++	Linux
PS SCOE	PXI, Lambda Genesys Power Supply		

Mission Related

- ✓Launcher Factory Test envinroment
- ✓Flexibility
- ✓Configurability
- ✓Simulation of LV element

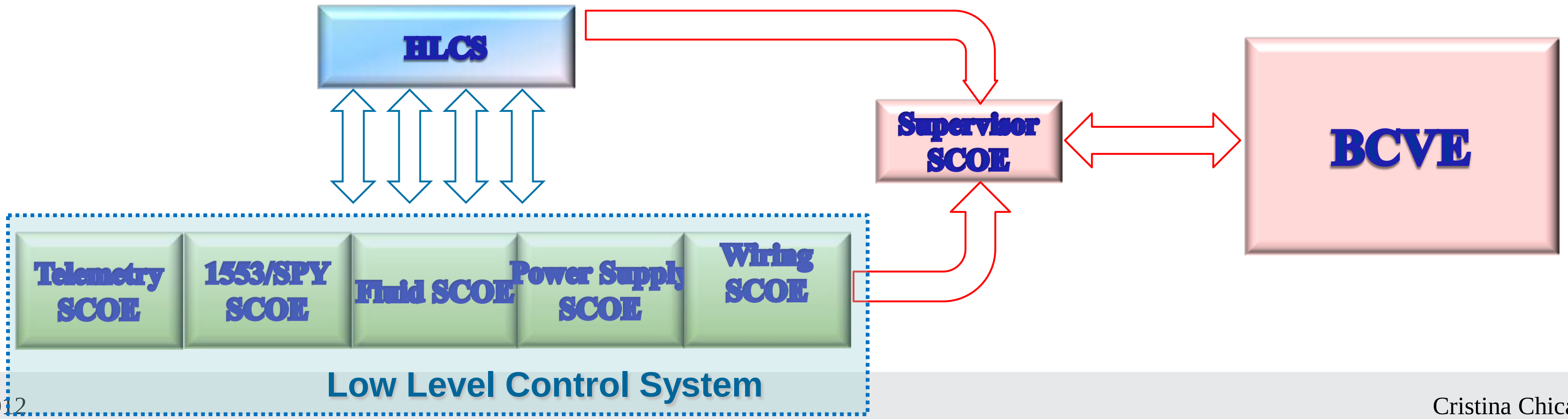
- ✓On Site Operational Envinroment
- ✓Hazardous operations
- ✓Safety rules
- ✓Ground Segment interfaces

Safety and reliability drivers

CCV is used in an operational environment which may include integrated launcher and/or hazardous operations like propellant filling.
Thus, it is subject to risk potentially impacting human life or in general concerning personnel damage.
Another important point is reliability, which implies also the prevention of uncontrolled operations on external equipment impacting mission

Emergency Subsystem

In order to avoid uncontrolled operations, a dedicated security system has been implemented which monitors the health status of Functional System, and, in case of failure, triggers the dedicated Emergency subsystem (BCVE)which put in safe status the LV or Ground.



Other Differences

✓EGSE TPE allows to write procedures Runtime

✓CCV HLCS accepts only procedures compiled and validated in CDC

✓CCV HLCS manages Safety-Related functions on parameters/commands management (forcing, barring, interception)

✓CCV has redundancy in PS SCOE, advance-delay fault protection

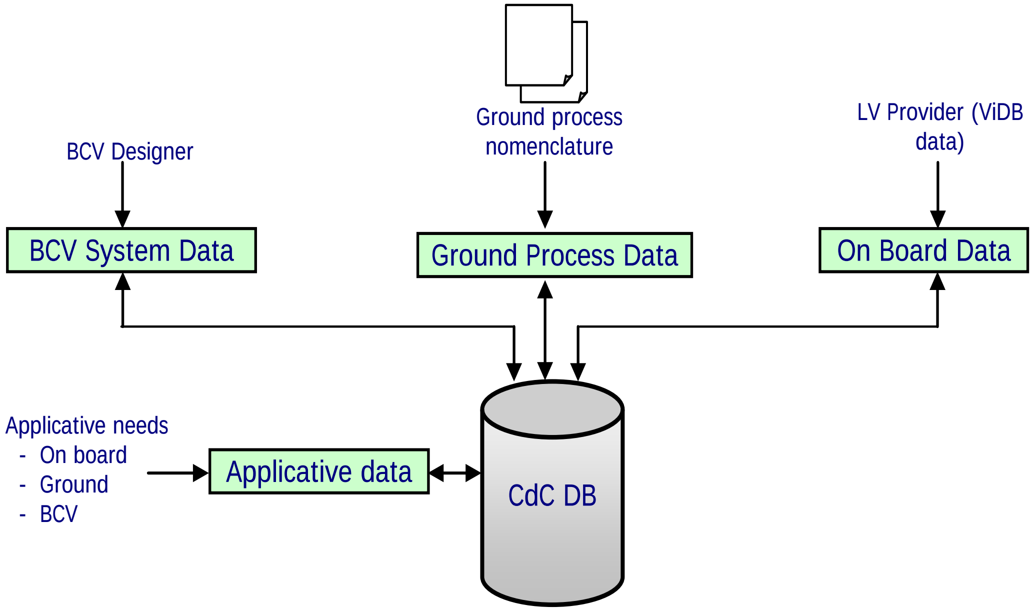
CCV input DB considers also Ground Interfaces and Ground Process Data

Launch Vehicle On Board Data: SCD, TM and Hardwired data

Ground Process Data: Hardwired data concerning Bunker/MG Ground Process, fluid subsystems, valves etc.

BCV System Reporting Data/Activities

Applicative Data: These data are not directly linked to a physical entity, but relevant to "applicative" needs, i.e. necessary to carry out operation and exploitation on the BCV.



→Management of Countdown, Countdown stop signals

Program Related

The CCV HLCS has a fully developed High Level Control System, with a Java-based architecture, completely developed by its manufacturer.

Requirements on parameters and command operations:
command barring, forcing, interception, parameter forcing, request flow

→Only a few part (less than 20%) of EGSE code was reusable with some modification to do.

The use of a new Java system has implied a revision of HLCS architecture, based on the fact that CCV HLCS is only an execution environment for LN3 code, subjected to a preliminary specification and validation process, while EGSE HLCS allows modifying runtime test sequences, which is more effective for a “test” environment.

In both cases deterministic real time behaviours are guaranteed at LLCS level by LLCSW, 1553 and PS SCOEs performing a UUT closed-loop monitoring

CHALLENGE

✓a wholesome EGSE, that includes a CCS and a set of SCOEs and avionic simulators, with omni-comprehensive requirements, tailored during the course of the development for the mission success.

✓a control bench for the launch of the VEGA, shifted in time vs the EGSE timing.

SOLUTION

Two products with the highest level of commonalities

- ensuring that the focus of each was maintained
- ensuring parallel development and tuning
- implementing a virtuous loop among the development of the two products

The two project experiences have brought a strong return of experience on LV lifecycle

- Convergence analysis is ongoing, to find optimization items and cost reduction options for future missions