ADCSS-2018 Command & Control
VEGA SPACE TRANSPORTATION SYSTEM PERSPECTIVE

STS-DVA

17/10/2018

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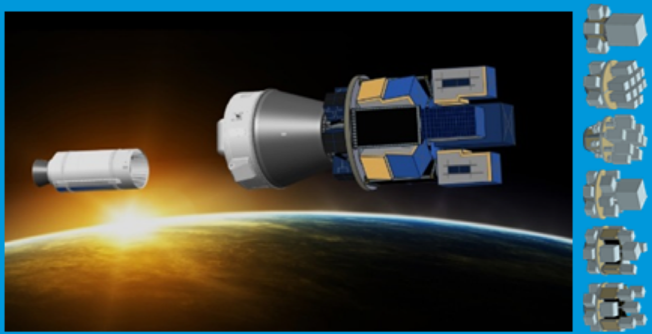

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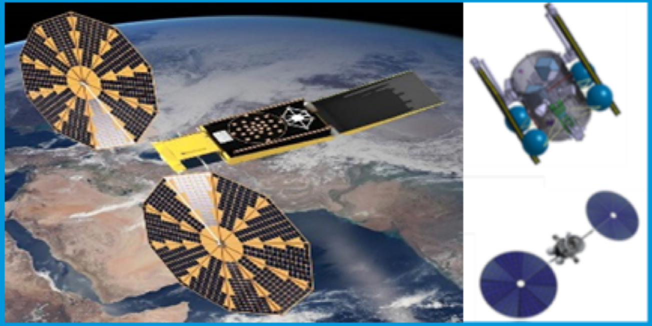

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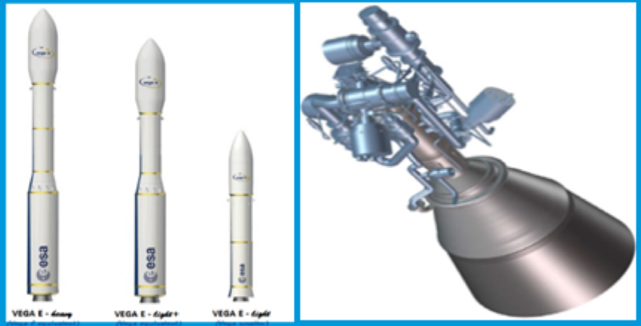
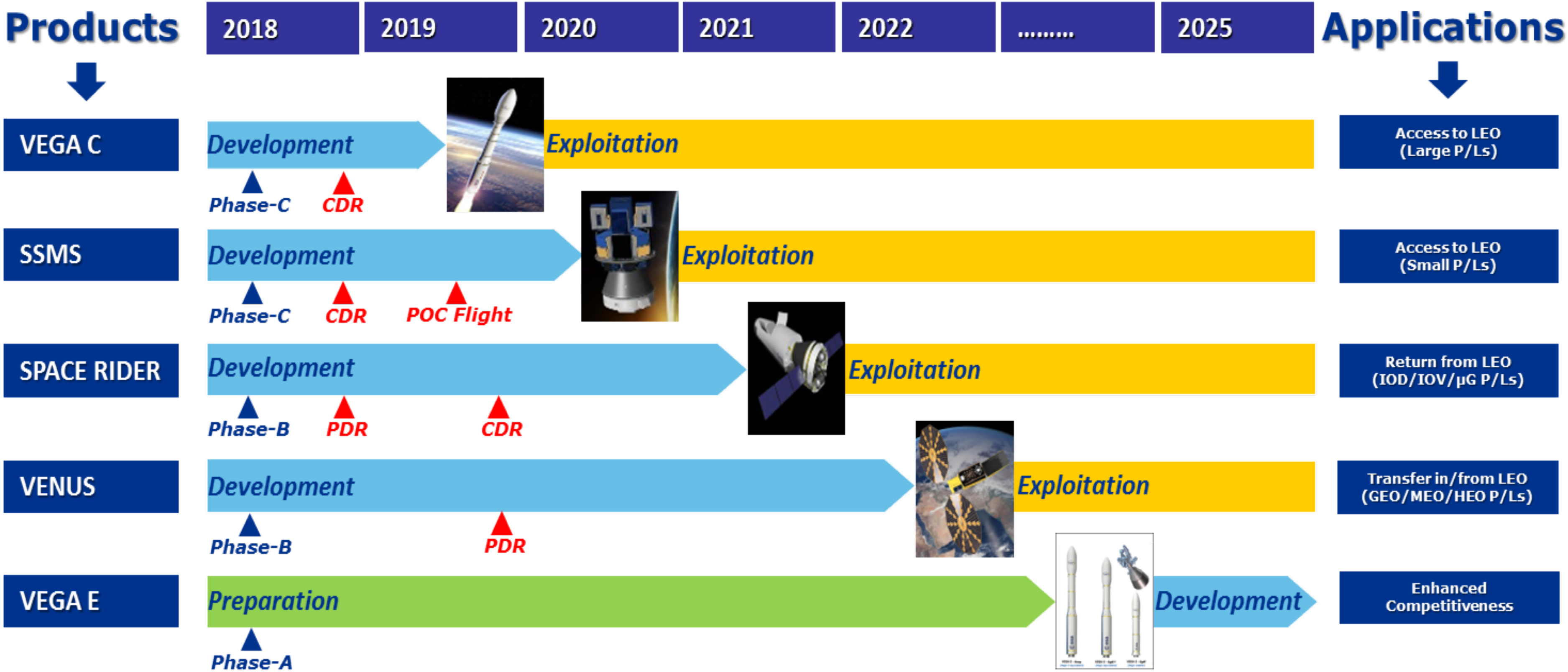


The Master Planning



VEGA-C Competitiveness Criteria

The following *key criteria* are considered the main drivers in the Launchers Domain and in particular in the VEGA Space Transportation System for the selection of fundamental technologies like Command and Control:

- **Performances**: The key indicators are Mass to Orbit, Injection accuracy. From there, requirements shall be flow-down at all levels. For instance, Communication Systems Response Time, Data Flow, Memory Availability, CPU margins, etc
- **Reliability and Availability**: Resilience to environments, correct balancing between simplicity and Advanced Features;
- **Observability**: This is a key driver on Launchers domain both on Ground and Flight operations:
- On ground: Quick failure Detection and Identification to allow efficient troubleshooting during Launch Campaign;
- In Flight: Real Time Health Monitoring, Safety related data transmission, Post-flight data exploitation and analysis;
- **Flexibility**: Intended as the capability to provide dedicated on-board and payload related services that can be adapted and/or modified efficiently, in short time (e.g. Payload reconfiguration) or even in real-time (e.g. adaptive control and robustness techniques). The capability to interchange communication protocols without introducing the need of re-designing the equipment is a key asset.
- **Autonomy**: Launchers have to be more and more autonomous and less depending on Ground means (e.g. implementation of Flight Termination Systems);

VEGA-C Competitiveness Criteria

- **Sustainability**: The electrical systems shall be easily upgradable without a major re-design, requiring low maintenance effort and providing modular design to ease the treatment of last-minute anomalies (e.g. replacement of a failure module), resilience towards obsolescence issues raised during the long exploitation life-cycle or compliance towards material-related regulations (eg. RoHS, REACH).
- **Safety**: The new systems shall ease the capability to segregate the Functional chain from the the Safety chains, allowing the implementation of redundancies wherever the qualitative requirements are imposed and providing the required observability; Other constraints to be taken into account like space debris removal.
- **Feasibility**: The technologies shall have a reasonable development and implementation time, adaptable to required and modifiable launch rates;
- **Affordability**: Very stringent exigences in terms of Non-Recurring Cost but mainly Recurring Cost, taking into account the constraints in terms of national contribution and European preference policy, national and international regulations (eg. ITAR or export licensing);

Vega-C Launcher System - HIGH LEVEL DRIVERS		FLOW-DOWN to Vega-C AVIONICS SYSTEM (VAS)	PROPOSED IMPROVEMENTS
RELIABILITY	QUANTITATIVE (RAMS figures)	No need identified: Vega avionics reliability figures compliant with Launcher System RAMS requirements	N/A
	QUALITATIVE	Simplex architecture --> Redundancies would be an asset	Redundancies in equipments and communication bus would be an asset (e.g., Navigation sensor, etc)
		Electrical interfaces limited robustness [see Vega REX on single point failures in harness & connectors]	1.- Removal of single point failures 2.- Innotavie approches for Electical IF (wireless, etc)
		SOFTWARE - Advanced SmartFDIR: Increased Failure detection & recovery capabilities	New Telemetry Subsystem --> Access of TLM measurements by FPSA to increase FDIR coverage (e.g. use of temperature measurements to verify correct LPS/RACS valve actuation and respective recovery actions, etc) FPSA evoluation --> a) Use GNC data to increase FDIR coverage (e.g. to detect RACS thruster failure and identify faulty unit) b) Perform controllability analysis in case of a RACS thruster failure and make GNC algorithm robust to such failure (once detected by advanced FDIR)
		Reduced Qualificaiton Margins in some equipments (RfDs, RfWs)	Review of all standing RfDs and RfWs from Vega (e.g. OBC computation RfW)
PERFORMANCES		Improved GNC algorithms & maneouvers --> To optimise the use of propulsion energy	See ESA-LAU-VG-MO-2016-30008 (LS-RKP REC#13)
MISSION FLEXIBILITY / VERSATILITY		Improved FPSA / GNC --> To enable more complex missions	
		Electrical Payload services --> Recurrent needs (or with medium-high probability)	N/A (To be adressed in MFU Mkii development)
		Electrical Payload services --> Specific needs (medium-low probability)	Optional Add-on unit MFU<->Payload I/F ecending MFU Mkii services
PROGRAMMATIC DRIVERS	RECURRENT COST	Equipment Recurrent cost	New developments design to cost oriented: 1.- IMU + GNSS Hybridation 2.- Telemetry Subsystem
		Electrical AIT (Equipment and Assy level)	
		Missionisation (Improvement of SW Factory)	See ESA-LAU-VG-MO-2016-30007 (LS-RKP REC#10)
		Increase Competition (increased control on supplier chain)	IRS replacement by MEMS/FOG+GNSS hybrid, Batteries
		Telemetry Launch range simplification	TDRS
		Safety Localisation launch range simplification	2nd IMU + GNSS hybrid +TDRS, aiming to the mid-long term simplification/removal of Radar ground stations network
	LIFETIME EXPLOITATION ROBUSTNESS	Obsolescence robustness	Multisourcing, Line-Replaceable Units, Architecture Standaridsation, Open architecture, Design to Obsolescence See ESA-LAU-VG-MO-2016-30006 (LS-RKP REC#18)
		Geo constraints (Export license, European geo-return, etc)	IRS Thales SW, JAVAD GPS receiver in ALS
SAFETY NON-COMPLIANCES	VERY NEAR FIELD ALGORITHM	Automatic neutralisation	Dedicated use during MSI of GNSS+IMU hybridation within SAS Subsystem
	NEUTRALISATION	Stages neutralisation / defragmentation	To be discussed with D.Lefalcher / D.Barbagallo
	LOCALISATION	ALS segregation (short term)	ALS+ or EL2K
		Redundant On-Board Safety localisation means (GNSS + IMU)	Dedicated use during MSI of GNSS+IMU hybridation within SAS Subsystem
TELEMETRY LIMITATIONS	MISSION FLEXIBILITY	Broader sensors types --> Seria/Digital inputs (RS-232, RS422, etc)	NEW TELEMETRY SYSTEM
		Increased Mass Memory capabilities	
		Add-on optional Video capabilities standarised	
		Possibility for higher bitrate (compression features, increased bandwithd / modulations, etc)	
	LAUNCH RANGE RECURRENT COST	Replacement of TLM Ground stations by Satellite link	TDRS, EDRS

VEGA-C 1553 Communication System

Usage of 1553 during the development, test and operations and during the proper VEGA-C mission.

It provides required functionality and performances in terms of determinism and real-time environment. However, even if studies exist to increase the data rates on existing MIL-STD-1553 networks beyond the current 1Mbps rate, no solution is yet available.

On top of that, the “protocol overhead”, “packet overhead” and “frame overhead” (which are today estimated at around 30%) further subtract the usable bandwidth.

In terms of Qualitative Reliability, the usage of simplex architecture is an asset (RAMS reliability figures are met with current configuration)

VEGA-C Telemetry System

The Telemetry Qualification configuration is composed of an extended set of units and modules to cope with the following acquisitions:

a) Hardwired signals connected to hardware channels (sensors, wired unit telemetries)

b) 1553 Telemetries acquired by the spying of the 1553 bus

c) Mass memory data

The system is composed of:

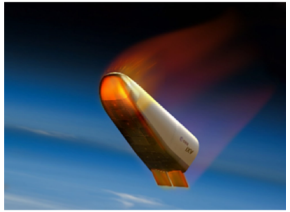
- Two Central Telemetry Units (CTUs) that acquire all the previous data, provides sensor conditioning, manage the mass memory and build the CCSDS frames. The unit installed in the upper part shall also be radiation tolerant.
- Two Telemetry Transmitters which receive PCM data from CTUs and transmit them to ground in S-Band.
- 6 Remote Telemetry Units (RTUs) which manage the acquisition of the different hardware channels for each stage.

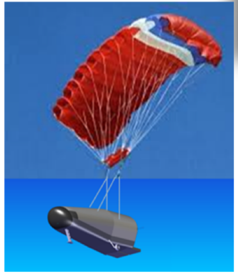
The communication between the CTUs and the peripherals RTUs is performed through a dedicated TM bus (Ethernet) which allows also the interface with the Ground Equipment.

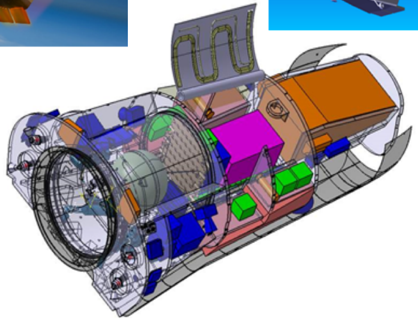
The network shall manage the lower stage separations in which the TM Bus is physically disconnected without impacting the working of the remaining units.

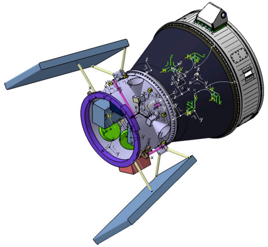
Space Rider Flight Segment - Introduction

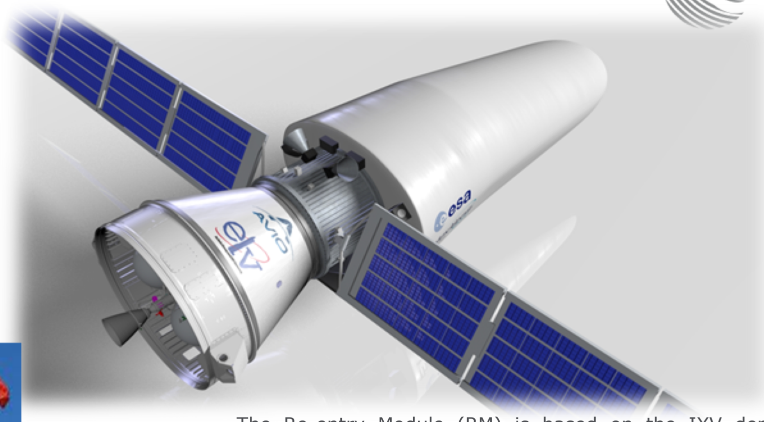
- The AOM is physically made of Standard AVUM and of the AVUM Life Extension Kit (ALEK) and acts as a service module during the orbital phase.
    - Provides power to the onboard systems and batteries through the solar arrays mounted on the ALEK.
    - Hosts sun sensors, star trackers and horizon sensors as is responsible for implementing GNC during orbital operations.
    - Responsible for small and large orbital manoeuvres based on a pre-defined MTL or uploaded manoeuvres from ground using a combination of reaction wheels, magnetorquers and RACS.
        - Attitude Change
        - Inclination change
        - De-orbiting











- The Re-entry Module (RM) is based on the IXV demonstrator to be modified as necessary to implement all the changes induced by the SPACE RIDER mission needs. It carries the experimentation payload inside the MPCB and it will return to Earth for re-flight.
    - Hosts the Multi Purpose Cargo Bay
        - 1200 L
        - 600-800 kg
    - Manages the TM/TC during orbital and re-entry operations
        - X band
        - Radar
    - RACS
        - 400N Thrusters
    - Body Flaps
        - 2 * Body Flaps for roll control
    - Descent System
        - TPS
        - Parachutes
        - Parafoil
    - Landing system
        - 3 point Landing Gear

Space Rider Avionics

Space Rider: RM – AOM Avionics interface

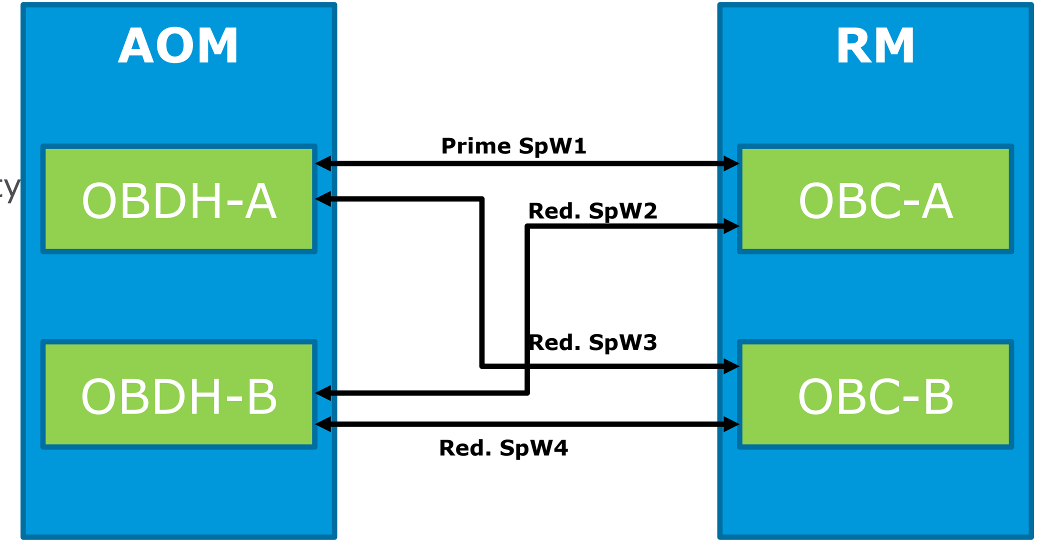
Communications between Orbital Module and Re-entry module is managed by SpaceWire, justified by the COTS program approach.

A full cross-strap redundancy scheme is implemented in the Point-to-Point link to avoid Single Point of Failure and to increase the flexibility of the configuration.

In case of reconfiguration of one module, the second module can continue working on the same lane.

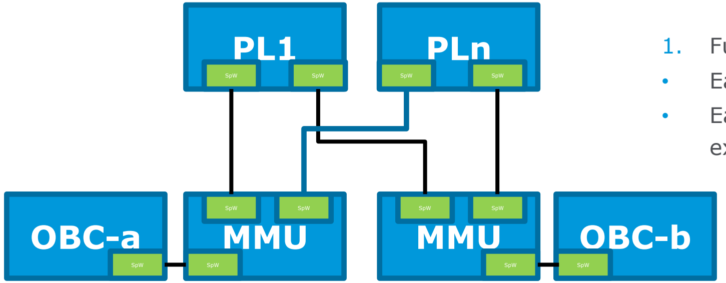
This is a simple architecture that requires low power per Mbit transmitted.

The full bandwidth can be used to transmit data from/to the two vehicles.



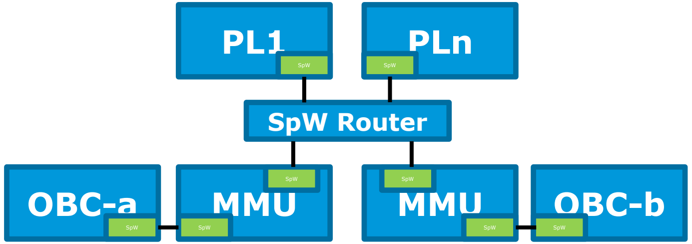
Space Rider RM – Payload I/F

Open trade-off for Payload Interface:

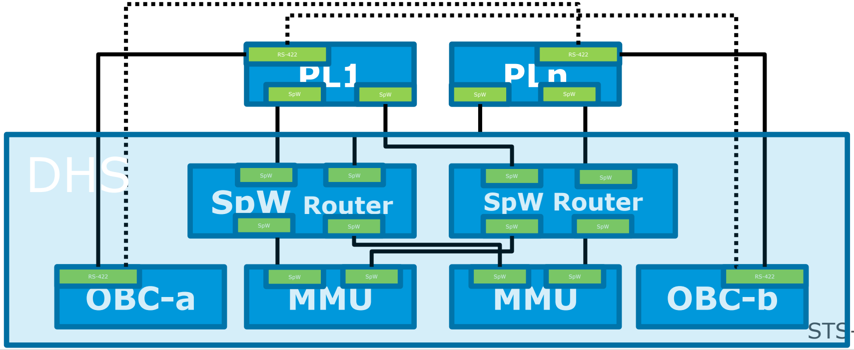


1. Full Redundant Approach:
- Each Payload shall provide two SpW data connectors
- Each link would be dedicated to the transmission of experimental data to one of the two MMUs.

2. Semi Redundant Approach:
- Addition of a SpW router to avoid the double data connector at PL level.
- The two MMUs are linked to the SpW router
- Management of the Single Point of failure at router level is needed.



3. SPF Free Configuration:
- This configuration provides a full redounded interface between Payload and Data Handling, in particular with the provision of a redounded SpW router.
- Possible implementation solution under evaluation at OBC level.



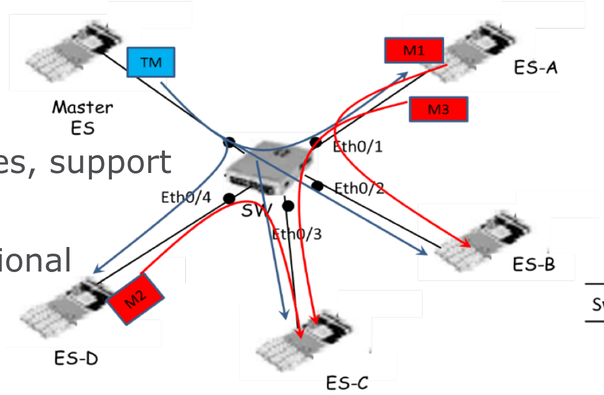
VEGA-C Evolutions

Ethernet Protocol

In the frame of common board design for different functionalities, in views of future launcher avionics architectures, the work to find standard Ethernet interface Boards to manage the communication with other avionic functions (e.g. telemetry, Actuation, Processing functions) and to collect communication bus telemetry data is being undertaken.

Main drivers for the usage of this protocol are:

- Deterministic behaviour is a must
- Predictability/Repeatability
- Support for cyclic traffic with different frequencies, support for sporadic traffic, bounded latency
- Time-Triggered communication providing operational flexibility
- Efficient usage of network bandwidth
- Usage of COTS components and standard libraries (task and interruption functions)



	Mesg ID	Sender	Receiver
M1	1	ES-A	ES-B
M2	2	ES-D	ES-C
M3	3	ES-A	ES-C

	Master ES	ES-A	ES-B	ES-C	ES-D
Switch Port	Eth0/0	Eth0/1	Eth0/2	Eth0/3	Eth0/4

- High level of flexibility through the centralization of the scheduling and the master/multi-slave transmission control (e.g. changing on-line the scheduled messages)

VEGA-C Evolutions

Some key **timing requirements** are:

- Maximum transfer time,
- Jitter non exceeding some threshold,
- guaranteed bandwidth.
- Synchronization accuracy in the sub-microsecond range with low computational capability thus reachable with standard low-cost devices.

Communication Protocol shall be based on a Cyclical concept with a fixed duration time frame to allocate traffic on the bus.

The cyclical concept should be made of two parts:

- Synchronous windows for cyclical and guaranteed exchanges managed by the Master Node that sends Triggered Messages to the N slaves. Such messages contain the identification of which information has to be sent and the associated delay and sends or receives Data Messages from the N slaves of the network.
- Asynchronous windows for on-demand traffic by the polling performed by the Master Node for real-time with less stringent constraints or for non-real time traffic.

Destination address	Source address	TPID	VLAN	Frame Length	Mess ID	Flags	SN	Payload

VEGA-C Evolutions

Final Objectives to achieve:

a) Usage of just one protocol, separate the functional traffic (mission critical) from other types of traffic like the telemetry (if this is not mission critical) or video streaming;

b) Failure containment. For instance, the switch should not forward failure messages to the high critical devices in case of malfunctioning of a terminal;

c) Enhanced bandwidth usage;

d) Possible usage of Technology improvements for Launchers:

- Line Replaceable Units // adaptation of SAVOIR for launchers;
- Standardised qualification factory (configurability, determinism, robustness)

Thank You!