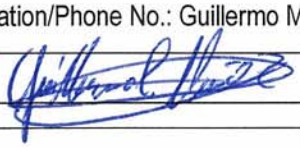
AMS CHANGE EVALUATION	
1. CR/DIR Number: AMS-02 / D-079	2. Page 2 of 2
3. Change Title: Baseline JSC 29788, AMS-02 Master Verification Plan (MVP)	
4. Evaluation Due Date: 23/01/2009	5. Return To: Mike Fohey [michael.fohey@escg.jacobs.com]
6. Evaluator/Organization/Phone No.: Guillermo Muñoz / Crisa / +34 918068664	
7. Signature: 	
8. Recommendation: ☐ Approved - As Written ☐ Disapproved – Reasons as stated below ☒ Approve with comments defined below ☐ No Comment/Recommendation	
9. Evaluation Of Technical Description/Impact/Remarks: Appendix E (Validation matrix for AMS-02 experiment hardware), CAB activities. The following Validation items/activities have been updated: CAB-5, CAB-7, CAB-9 & CAB-11 To show the present requirements applicable to CAB CCS subsystem electronics. Updated table is attached with the changes marked in blue colour.	
10. Evaluation Of Nonincorporation: The changes proposed in the verification table are only stated to identify the new applicable requirements	
11. Change Proposer's Disposition Of Evaluation:	

APPENDIX E: REQUIREMENT VERIFICATION MATRIX FOR AMS-02 EXPERIMENT HARDWARE

Validation Product #[1]	Activity[2]	Objective[3]	Valid. Method[4]	Facility or Lab[5]	Phase[6]	Perform. Org[7]	Results[8]
		3.3.1.2.11.2 Cryomagnet Avionics Box (CAB)					
CAB-1	HW Design Description	The Cryomagnet Avionics Box CAB is designed to perform all control and monitoring functions for Organization responsible of system tests the Cryomagnet Subsystem (including SFHe Tank and Vacuum Case). The CAB consists of four sections: the Cryomagnet Current Source (CCS); the Cryo Controller and Signal Conditioner (CCSC); the Cryomagnet Self Protection (CSP); and the Power Switches (PS)	*N/A*	N/A	N/A	N/A	N/A
CAB-2	AMS02 Integration	The CAB is located on the Unique Support Structure (USS) very close to the current input port of the Vacuum Case to minimize the length of the Cryomagnet Current Leads.	*Inspection*	System integration lab.	System-level	Organization responsible of system tests	System Inspection sheet

Validation Product #[1]	Activity[2]	Objective[3]	Valid. Method[4]	Facility or Lab[5]	Phase[6]	Perform. Org[7]	Results[8]
CAB-3	HW Design	High Voltage Isolation is provided at all inputs to the CAB from the ISS side to prevent passing any high-voltage that could be developed during a multiple fault "unassisted" quench back to the ISS power or data systems. Isolation for the 120Vdc line (feed thru from PDS) is performed via DC-to-DC Converters in the CCS. Analysis has shown that the maximum voltage that could be achieved during an "unassisted" quench is 5.5kV. 8kV isolation is provided at all these points to ensure margin. The unassisted quench is an off-nominal scenario, and would result in damage to the CAB and the magnet that would render them unusable, but not create a safety hazard. The one fault "assisted" quench would prevent these voltage levels from arising and protect the CAB and the magnet for mission success.	*Analysis*	CRISA	Prior to PDR	CRISA	CAB Design Description
		3.3.1.2.11.3 Cryomagnet Current Source (CCS)					
CAB-4	HW Design	The 120 Vdc Power input (feed through from the PDS) is routed solely to the Cryomagnet Current Source (CCS). A DC-to-DC converter at the input to the CCS provides isolation for this Power Bus. The 120 Vdc power is required only for magnet charging. All other sections of the CAB are operated with 28 Vdc from the PDS.	*Analysis*	CRISA	Prior to PDR	CRISA	CAB Design Description

Validation Product #[1]	Activity[2]	Objective[3]	Valid. Method[4]	Facility or Lab[5]	Phase[6]	Perform. Org[7]	Results[8]
CAB-5	HW Design and Test	The 120 Vdc input is limited to a maximum of 1875 W for power management. **NOTE.- Regarding the 500W magnet power limitation to guarantee a magnet current ramp rate lower than 2 Amps per minute, the maximum power consumption from 120 Vdc bus is 1200W (Magnet, Electronics, Current Shunt and cabling power dissipation) when charging the magnet with either 6 or 5 CCS CVs.**	*Analysis and Test*	CRISA and CERN	Box and System Tests	CRISA and Organization responsible of system tests	CAB Test Report Magnet Test Report
CAB-6	HW Design	Power supplied to the DC-to-DC converter is controlled by Opto-Isolating feedback from the DC-to-DC converter output with a power switch and pulse width modulation of the input.	*Analysis*	CRISA	Prior to PDR	CRISA	CAB Design Description
CAB-7	HW Design and Test	To charge the magnet, the Semiconductor switch on the charging circuit is closed, and power is supplied to the transformer input. The current is slowly ramped up over a period of approximately **2.5 hours to 424 Amps**. Current during charge and discharge operations is monitored using a 500A shunt **NOTE.- The magnet can be charged at any value of current between 50 Amps and the maximum full current of 424A.**	*Analysis and Test*	CRISA and CERN	Box and System Tests	CRISA and Organization responsible of system tests	CAB Test Report Magnet Test Report
CAB-8	AMS02 Integration	The connection from the CCS to the magnet is made via three pairs of AWG 2/0 wires. Once full operating current is reached, the Persistent Switch is closed (the switch consists of a pair of super-conducting wires – "closed" by cooling them down to superconducting temperatures)	*System Test*	CERN	System-level	Organization responsible of system tests	System test report

Validation Product #[1]	Activity[2]	Objective[3]	Valid. Method[4]	Facility or Lab[5]	Phase[6]	Perform. Org[7]	Results[8]
CAB-9	HW Design and Test	With the persistent switch closed, **the magnet full current** is running through both sides of the circuit (the magnet side and the charger side).To avoid ripple currents through the persistent switch, the current on the charger side is slowly reduced to zero. Once the current on the charger side is depleted, the Semiconductor Switch is opened, and the Charging System is disconnected from the Magnet Circuit.	*Analysis and Test*	CRISA and CERN	Box and System Tests	CRISA and Organization responsible of system tests	CAB Test Report Magnet Test Report
CAB-10	HW Design and Test	If an event occurs that necessitates a power down of the magnet, the system is designed to perform a nominal "ramp down" function. The nominal ramp down is the most acceptable method for powering down the magnet without the potential for substantially decreasing the endurance of the magnet.	*Analysis and Test*	CRISA and CERN	Box and System Tests	CRISA and Organization responsible of system tests	CAB Test Report Magnet Test Report

Validation Product #[1]	Activity[2]	Objective[3]	Valid. Method[4]	Facility or Lab[5]	Phase[6]	Perform. Org[7]	Results[8]
CAB-11	AMS02 Integration	To perform a ramp down, the mechanical leads are connected and the persistent switch is opened (by allowing it to warm to a non-superconducting state), The connection from the magnet is to the CAB with three pairs of AWG 2/0 wires, and then on to the CDD, with a loop of one AWG 2/0 wire. The energy from the magnet is dissipated in the form of heat through the CDD chain. The CDD consists of **three** sets in series of three diodes in parallel that are used solely for the purpose of dissipating the stored energy of the magnet. **These dump diodes are located on the wake / startboard-side sill trunnion joint, directly above the CAB, which was selected for its large thermal mass**. The CDDs are protected by a metal cover to prevent incidental contact by ground personnel or crew. The total time required to dissipate the magnet energy is estimated to be **134 minutes**	*System Test*	CERN	System-level	Organization responsible of system tests	System test report
		3.3.1.2.11.4 Cryomagnet Control and Signal Conditioning (CCSC)					

Validation Product #[1]	Activity[2]	Objective[3]	Valid. Method[4]	Facility or Lab[5]	Phase[6]	Perform. Org[7]	Results[8]
CAB-12	HW Design and Test	The CCSC provides the interface between the AMS-02 Main Data Computers (MDCs) and the Cryomagnet. The CCSC is responsible for: □reception of commands from the MDCs □transmission of telemetry to the MDCs □commanding of the CCS □control of the Cryomagnet auxiliary functions (i.e. heaters, valves, etc.) □monitoring of the CCS, Cryomagnet, and CAB operating parameters and status The CCSC also performs system fault detection and management functions, formatting of telemetry, and data storage for system status. The CCSC is required to interface with the Uninterruptible Power Source (UPS).	*Analysis and Test*	CRISA and CERN	Box and System Tests	CRISA and Organization responsible of system tests	CAB Test Report Magnet Test Report
		3.3.1.2.11.5 Power Switches					
CAB-13	HW Design and Test	The power switches control the 28 VDC power supply to valves and cryogenic heaters. With the exception of the power switches controlled directly by the CSP, the power switches are galvanically isolated from the 28 VDC power bus.	*Analysis and Test*	CRISA and CERN	Box and System Tests	CRISA and Organization responsible of system tests	CAB Test Report Magnet Test Report
		3.3.1.2.11.6 Cryomagnet Self Protection (CSP)					

Validation Product #[1]	Activity[2]	Objective[3]	Valid. Method[4]	Facility or Lab[5]	Phase[6]	Perform. Org[7]	Results[8]
CAB-14	Magnet Description	Super-conducting magnets, such as the one utilized by AMS-02, may develop a condition where a portion of the coil begins to rise above super-conducting temperatures. When this condition occurs, the section of wire affected begins to develop resistance, and the current running through this resistance begins to heat the wire rapidly. This eventually leads to dissipation of the magnet energy (in the form of heat) within the magnet, and is referred to as a magnet quench. This condition is highly undesirable from a mission success standpoint because resulting unbalanced magnetic forces in the different sections of the magnet may cause it to deform, making it unable to be recharged to the maximum field or even to return to a superconducting state, thus preventing the recharging of the magnet. This is a possible mission success critical failure, not a safety issue. Alterations in the magnetic field have already been accounted for in the safety assessment for nominal field strengths.	*Analysis*	CERN	Magnet System	SCL	Magnet Report

Validation Product #[1]	Activity[2]	Objective[3]	Valid. Method[4]	Facility or Lab[5]	Phase[6]	Perform. Org[7]	Results[8]
CAB-15	HW Design and Test	To protect the magnet from this condition, referred to as an unassisted quench, electronics have been designed that will detect the initiating condition and apply heat quench evenly throughout the magnet coils, causing the magnetic field to dissipate uniformly. This will prevent the heating from being isolated to a small section of the magnet, which could become damaged if the quench was uncontrolled. By performing an assisted quench, mission success criteria can be maintained. The Cryomagnet Self Protection (CSP) section of the CAB was developed to detect a change in voltage across a coil and perform this assisted quench.	*Analysis and Test*	CRISA and CERN	Box and System Tests	CRISA and Organization responsible of system tests	CAB Test Report Magnet Test Report
CAB-16	HW Design and Test	The CSP contains quench detection electronics that monitor the status of the magnet coils to determine if a quench condition is starting to occur. To perform this function, redundant voltage measurements are taken across each coil. If a quench condition is imminent, a voltage will develop across the affected coil. When the CSP detects a change in voltage, the quench protection electronics issues a command to the Uninterruptible Power Source (UPS) to provide a pulse of at least 45A to quench heaters located throughout the magnet. The pulse, for a duration of 150 ms, is required to raise the entire magnet up to a non-superconducting state. This spreads the quench throughout the magnet and prevents isolated heating that could result in degraded performance.	*Analysis and Test*	CRISA and CERN	Box and System Tests	CRISA and Organization responsible of system tests	CAB Test Report Magnet Test Report

Validation Product #[1]	Activity[2]	Objective[3]	Valid. Method[4]	Facility or Lab[5]	Phase[6]	Perform. Org[7]	Results[8]
CAB-17	HW Design and Test	The quench heater chains are redundant and supplied by two separate UPS systems. The chains are routed to alternate coils throughout the magnet. Both heater chains are nominally used by the CSP to control a quench, however either chain independently is sufficient to protect the magnet coils from deformation.	*Analysis and Test*	CRISA and CERN	Box and System Tests	CRISA and Organization responsible of system tests	CAB Test Report Magnet Test Report
CAB-18	HW Design and Test	The CSP provides additional functions to protect the magnet during off-nominal conditions. A "watch dog" timer, powered by the UPS, is continuously counting down. Periodically the timeout is reset via external command to about 8 hours. In the event of a power loss, or the loss of communication to the AMS-02 payload, the timeout is not reset and if power or communications are not restored to the AMS within the eight-hour period, the timer will trigger the CSP Control Electronics to initiate the nominal ramp down function, discharging the magnet. During the eight hour period and the ramp down, the UPS will continue to power the Quench Detection Electronics, and maintain the capability to perform an assisted quench (if necessary) until the magnet is completely discharged. ....wording deleted...	*Analysis and Test*	CRISA and CERN	Box and System Tests	CRISA and Organization responsible of system tests	CAB Test Report Magnet Test Report

		3.3.1.2.11.7 CSP Uninterruptible Power Source (UPS)					
CAB	UPS Description	The UPS consists of dual redundant 28 Amp-hour (A-h) Lithium Ion Batteries and a Battery Management System (BMS) for each, developed by Yardney/Lithion Corporation, Pawcatuck, CT. Each battery consists of eight cells in series to generate the required nominal 28 Vdc for the system. To ensure mission success during loss of ISS power or communication, the UPS is required to supply power for the watchdog timer function, quench monitoring functions, nominal ramp-down at watchdog timer rundown, and initiation of a quench pulse of at least 45 A for 150ms anytime during the sequence.	*Analysis and Test*	CRISA and CERN	Box and System Tests	CRISA and Organization responsible of system tests	CAB Test Report UPS Test Report

CAB	HW Design and Test	The CAB BCE design includes the following protection electronics: Two double diodes in a cross-strapping configuration of the nominal and redundant 28Vdc primary power busses coming from PDS unit. SSPC (Solid State Power Conditioner), implemented by means of an Latching CurrentLimiter (LCL), which opens in case of failure. The HV power transformer barrier, which provides galvanic isolation between the electronics on primary side and the electronics on secondary side. The control electronics to provide the fit current to the battery, and also includes a power transformer with galvanic isolation. The blocking diode included in the BMS Battery Management System Electronics, which only permits the current way in only one direction. All the above-mentioned protections included in the CAB BCE guarantee no propagation of failure to the ISS or any other unit, such as the PDS, which provides the 28Vdc primary power busses.	*Analysis and Test*	CRISA	Box Tests	CRISA	CAB Test Report

CAB	HW Design and Test	The CSP electronics design includes the following protection electronics between UPS and the loads (quench heaters, magnet valves): □Two switches in series to power the quench heaters. These switches are only closed during 150ms of time required for the quenching sequence. □SSPC (Solid State Power Conditioner), implemented by means of an LCL Latching Current Limiter, which opens in case of failure. □The power transformer barrier, which provides galvanic isolation between the electronics on secondary side and the electronics on the load side. □Two switches in series to open or close the valves.	*Analysis and Test*	CRISA	Box Tests	CRISA	CAB Test Report

[1] *Unique identifier for verification product – include detector or subsystem identifier (i.e. TRD–X, TCS–Y, Electronics–Z, etc.)*
[2] *Provide a short title of activity performed (Beam Test of …, Inspection of … Hardware to Drawing , etc.)*
[3] *Describe requirement that will be verified*
[4] *Verification Method for the AMS-02 requirement (Analysis, Inspection, Demonstration, or Test)*
[5] *Facility or laboratory used to perform the validation*
[6] *Phase in which the verification/validation will be performed:*
Example:
1. *During product selection process*
2. *Prior to final product selection (if COTS) or prior to PDR*
3. *Prior to CDR*
4. *During box-level Functional*
5. *During System-level Functional*
6. *During end-to-end Functional*
7. *During Integrated Vehicle Functional*
8. *During On-orbit Functional*

[7] *Organization responsible for coordinating the verification activity*
[8] *Indicate the objective evidence that verification activity occurred (i.e. Analysis Report No., Test Report No., Inspection Sheet No., etc.*