IEC 61508 Functional Safety Assessment

Project:

Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter

Customer:

Magnetrol International, Inc.
Aurora, IL
USA

Contract No.: Q09/10-39, Q14/09-006
Report No.: MAG 09/10-39-R005
Version V1, Revision R4, December 5, 2014
Griff Francis

Management Summary

This report summarizes the results of the functional safety assessment according to IEC 61508 carried out on the:

Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter

The functional safety assessment performed by *exida* consisted of the following activities:

- *exida* assessed the systematic capability through an analysis of proven-in-use data and creation of a detailed safety case against the requirements of IEC 61508.
- *exida* reviewed and assessed a detailed Failure Modes, Effects, and Diagnostic Analysis (FMEDA) of the devices to document the hardware architecture and failure behavior.

The functional safety assessment was performed to the requirements of IEC 61508, SIL 3. All documents referenced in sections 2.4.1 and 2.4.3 were reviewed and form the basis of this assessment.

The results of the Functional Safety Assessment can be summarized by the following statements:

The Eclipse Enhanced Model 705 3X Level Transmitter was found to meet the requirements of SIL 2 for random integrity @HFT=0, SIL 3 for random integrity @ HFT=1 and SIL 3 for systematic capability.

The manufacturer will be entitled to use the Functional Safety Logo.

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1 Purpose and Scope

This document shall describe the results of the IEC 61508 functional safety assessment of the Magnetrol International, Inc.:

- Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter

by *exida* according to the requirements of IEC 61508: ed1, 2000.

The purpose of the assessment was to investigate the compliance of:

- the Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter with the technical IEC 61508-2 and -3 requirements for SIL 3 and the derived product safety property requirements

and

- the Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter development processes, procedures and techniques as implemented for the safety-related deliveries with the managerial IEC 61508-1, -2 and -3 requirements for SIL 3.

and

- the Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter hardware analysis represented by the Failure Mode, Effects and Diagnostic Analysis with the relevant requirements of IEC 61508-2.

The assessment has been carried out based on the quality procedures and scope definitions of *exida*.

The results of this assessment provide the safety instrumentation engineer with the required failure data as per IEC 61508 / IEC 61511 and confidence that sufficient attention has been given to systematic failures during the development process of the device.

1.1 Tools and Methods used for the assessment

This assessment was carried by using the *exida* Safety Case tool. The Safety Case tool contains the *exida* scheme which includes all the relevant requirements of IEC 61508.

For the fulfillment of the objectives, expectations are defined which builds the acceptance level for the assessment. The expectations are reviewed to verify that each single requirement is covered. Because of this methodology, comparable assessments in multiple projects with different assessors are achieved. The arguments for the positive judgment of the assessor are documented within this tool and summarized within this report.

2 Project management

2.1 *exida*

exida is one of the world's leading accredited Certification Bodies and knowledge companies specializing in automation system safety and availability with over 300 years of cumulative experience in functional safety. Founded by several of the world's top reliability and safety experts from assessment organizations and manufacturers, *exida* is a global company with offices around the world. *exida* offers training, coaching, project oriented system consulting services, safety lifecycle engineering tools, detailed product assurance, cyber-security and functional safety certification, and a collection of on-line safety and reliability resources. *exida* maintains a comprehensive failure rate and failure mode database on process equipment based on 100 billion hours of field failure data.

2.2 Roles of the parties involved

Magnetrol International, Inc.	Manufacturer of the Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter
exida	Performed the hardware assessment
exida	Performed the Functional Safety Assessment per the accredited *exida* scheme.

Magnetrol International, Inc. contracted *exida* in October 2009 with the IEC 61508 Functional Safety Assessment of the above mentioned devices. Magnetrol International, Inc. contracted *exida* again in September 2014 to renew the certification.

2.3 Standards / Literature used

The services delivered by *exida* were performed based on the following standards / literature.

[N1]	IEC 61508 (Parts 1 - 7): 2000	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems

2.4 Reference documents

2.4.1 Documentation provided by Magnetrol International, Inc.

	[Safety Case Doc]; Rev; Date	Description
[D1]	[D01]; V0R1; 6/3/2010	Functional Safety Management Plan - Not required for PIU with modification restrictions, included for reference
[D2]	[D110]; 10/28/2005	EMC CE COMPLIANCE TEST REPORT Enhanced Model 705 Eclipse Transmitter
[D3]	[D111]; 11/1/2003	WIB Evaluation of Eclipse 705
[D4]	[D119]; 3/29/2011	*exida* Validation Test Execution Phase Checklist

[D5]	[D150];	*exida* Functional Safety Assessment Phase Verification Checklist
[D6]	[D160]; 6/1/2010	Product Safety Manual
[D7]	[D161]; NA; 7/20/2010	*exida* Safety Manual Checklist
[D8]	[D162]; 9/1/2007	Eclipse 3X Installation and Operating Manual
[D9]	[D165]; V3R1; 2/11/2010	Failure Modes, Effects and Diagnostics Analysis (FMEDA) Report
[D10]	[D166];	exida FMEDA Document Checklist
[D11]	[D181]; Rev 12; 7/12/2011	Engineering Change Request And Change Notice
[D12]	[D189]; 3/29/2011	*exida* Modification Phase Verification Checklist
[D13]	[D20]; 5/31/2011	ISO 9001 Certificate
[D14]	[D21]; Rev 1.3; 12/4/2009	Magnetrol SAFETY CRITICAL PRODUCT DEVELOPMENT AND MAINTENANCE
[D15]	[D22]; Rev 23; 8/3/2009	Quality Management System Manual
[D16]	[D23]; Rev 1.1; 7/1/2009	C Coding Standard for Safety Related Software Development
[D17]	[D24]; Rev 14; 7/21/2010	Supply Base Control Plan (Vendor Qualification Procedure)
[D18]	[D25]; 7/27/2009	Magnetrol Software Development Methodology
[D19]	[D26];	Safety Training Records
[D20]	[D27]; Rev 1; 12/16/2010	RMA Processing
[D21]	[D28]; Rev 4; 7/29/2010	Corrective Action Procedure
[D22]	[D29]; Rev 0; 7/14/2011	Customer Notification
[D23]	[D30]; V0 R2; 7/12/2011	Safety Requirements Specification - Not required for PIU with modification restrictions; added for reference
[D24]	[D31];	*exida* SRS Document Checklist
[D25]	[D32]; 7/13/2011	Safety Requirements Specification Review Meeting Minutes
[D26]	[D45]; 6/2/2005	Enhanced Model 705 Warnings and Faults for SIL 1 and SIL 2
[D27]	[D46]; V1R1; 4/29/2011	Proven Operational Experience Calculation and Report
[D28]	[D47]; 4/29/2011	Eclipse 3X Proven In Use Data
[D29]	[D48]; 3/29/2011	*exida* Proven In Use Checklist
[D30]	[D53]; 4/5/2010	Fault Injection Test Plan
[D31]	[D54];	*exida* HW Fault Injection Test Verification Checklist
[D32]	[D55]; see individual schematics;	Eclipse 3x Schematics

[D33]	[D56];	Eclipse 3x schematics with fault injection points
[D34]	[D57]; Rev4; 7/15/2011	Fault Injection Test Results
[D35]	[D68]; 7/26/2011	Component Level FMEDA
[D36]	[D71];	Detailed Software Design Specifications
[D37]	[D80]; 1.0; 6/9/2010	IEC 61508 Tables not covered in FSM Plan

2.4.2 Documentation provided by Magnetrol International, Inc. for Re-Certification October 2014

	Document Number, Revision, Date	**File Name**	**Description**
[D38]	_,_,27 Aug 2013	New Product Development Process Flow.pdf	Overall Development Process
[D39]	_,_,_	Dev Process Steps.xlsx	Overall Development Process- Step Description
[D40]	SLA-007, 00, 8 Jul 2013	SLA007.pdf	Modification Procedure
[D41]	SKA-002, 14, 23 Sep 2013	SKA002.pdf	Modification Procedure - EC
[D42]	_,_,25 Sep 2014	705-51A SHIPMENTS.xlsx	Shipment Records
[D43]	_,_,18 Sep 2014	705 3X SIL RMAs SUMMARY 080111 TO 091614.xlsx	Field Returns Records
[D44]	CERT-0079004, 28 Apr 2014	ISO 9001-2008 Certificate - May 2014.pdf	ISO 900x Certificate
[D45]	094-6052, G, 18 Jun 2010	094-5062-A.PDF	SCHEMATIC, ENHANCED 705 DIGITAL P.C. BOARD
[D46]	094-5062, A, 8 Jan 2008	094-6052-G.PDF	SCHEMATIC, HART WIRING BOARD
[D47]	094-6051, N, Oct 2009	094-6051-N.PDF	SCHEMATIC, ENHANCED 705 ANALOG P.C. BOARD
[D48]	_,_,3 Oct 2014	705 3X SIL 2 CHANGES 100314.xlsx	Hardware Change List
[D49]	_,_, 20 Jun 2011	SC-1260.1AMDL 705 3X HART 5 TO 6	Validation Test Results

		TESTING.xlsx	
[D50]	_,_, 1 Apr 2011	M705 3x HART 5 to 6 Upgrade Common Practice Commands Tests.pdf	Validation Test Results 2
[D51]	_,_, 1 Apr 2011	M705 3x HART 5 to 6 Upgrade Data Link Layer Tests.pdf	Validation Test Results 3
[D52]	_,_, 1 Apr 2011	M705 3x HART 5 to 6 Upgrade Universal Commands Tests.pdf	Validation Test Results 4
[D53]	_,_, 18 Nov 2014	Exida summary of Rev N schematic changes for Fid Ticks over temperature.xlsx	Validation Test Results 5
[D54]	57-651.3,_, Mar 2012	57-651.3 Eclipse 705 SIL IO.pdf	Safety Manual
[D55]	3177-00755,_, 6 Jan 2010	ECN 3177-755 screen shot.docx	Engineering Change Documentation
[D56]	_,_,28 Mar 2011	M705 3X HART 5 TO 6 MIGRATION IMPACT ANALYSIS.docx	Impact Analysis Record

2.4.3 Documentation generated by *exida*

[R1]	MAG 09-10-39 R005 V1R4 IEC 61508 Assessment Eclipse 3X.doc, 5 December 2014	IEC 61508 Functional Safety Assessment, Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter (this report)
[R2]	MAG 09/10-39 R001 V3R1 FMEDA Report , 26 July 2011	Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter FMEDA Report
[R3]	MAG 09/10-39 R004 V1R1 PIU Report , 29 Apr 2011	Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter PIU Analysis-Report
[R4]	Eclipse 3X IEC61508 SafetyCase 1Aug2011.esc	Safety Case DB- previous PIU certification
[R5]	Magnetrol 705 PIU Spreadsheet.xls, 29 Oct 2014	Calculation of actual field failure rate / PIU Analysis

[R6]	MAG 705 V1R1 Change Audit Checklist_form.xls, 19 Nov 2014	Change Audit Checklist (referenced by SafetyCaseWB)
[R7]	MAG 705 V1R1 Safety Case WB-61508 v1.7.2d.xlsm, V1R2, 5 Dec 2014	SafetyCaseWB

3 Product Description

The Eclipse Enhanced Model 705 Guided Wave Radar Level Transmitter is a loop-powered, 24 VDC level transmitter, based on Guided Wave Radar (GWR) technology. For safety instrumented systems usage it is assumed that the 4 – 20mA output is used as the primary safety variable. The analog output meets NAMUR NE 43 (3.8mA to 20.5mA usable). The transmitter contains self-diagnostics and is programmed to send its output to a specified failure state, either low or high upon internal detection of a failure (output state is programmable). The device can be equipped with or without display.

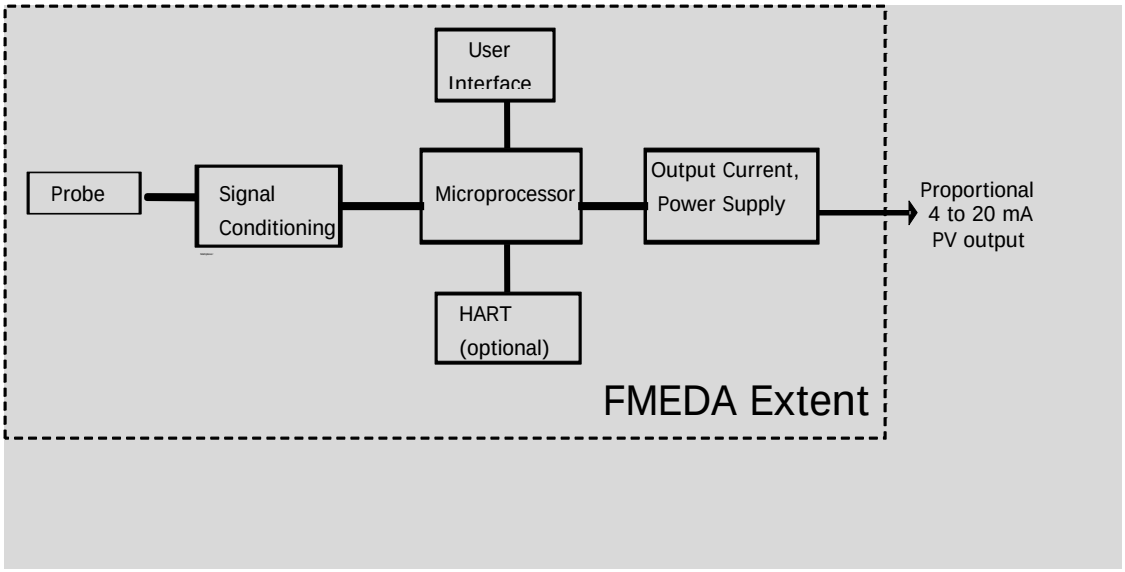


Table 1 lists the versions of the Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter that have been considered for the hardware assessment.

Table 1 Version overview

	Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter, 705-51Ax-xxx

Guided Wave Radar is based upon the principle of TDR (Time Domain Reflectometry). TDR utilizes pulses of electromagnetic energy transmitted down a probe. When a pulse reaches a surface that has a higher dielectric than the air/vapor in which it is traveling, the pulse is reflected. An ultra high-speed timing circuit precisely measures the transit time and provides an accurate level measurement.

Choosing the proper Guided Wave Radar (GWR) probe is the most important decision in the application process. The probe configuration establishes fundamental performance characteristics. Coaxial, twin element (rod or cable), and single element (rod or cable) are the three basic configurations. The probe for use with the Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter should be selected as appropriate for the application. Careful selection of probe design and materials for a specific application will minimize media build-up on the probe.

The Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter is classified as a Type B[1] device according to IEC61508, having a hardware fault tolerance of 0.

3.1 Scope of Analysis

The following were considered in this analysis:

Digital Board	094-6052, Rev F
Analog Board	094-6051 Rev M
Wiring Board	094-5062, Rev A

The IEC61508 certified 705-51A*-*** will be distinguished from the previous non-certified version by the serial number. The certification will apply to serial numbers starting at 648100-01-001.

4 IEC 61508 Functional Safety Assessment

The IEC 61508 Functional Safety Assessment was performed based on the information received from Magnetrol International, Inc. and is documented in this section.

4.1 Methodology

As part of the IEC 61508 functional safety assessment, the following aspects have been reviewed:

Documents:

- FMEDA
- safety manual
- instruction manual
- HW fault inject test plan and results verification
- SW design specification
- EMC test report
- Validation test results
- Corrective Action and prevention action plan/process

No ASICs are used in this product

No safety related communications are used in this product

Proven-In-Use (PIU) assessment provides for the prevention of systematic failures for pre-existing devices with a proven history of successful operation. As part of the IEC 61508 PIU assessment, the following aspects have been reviewed:

- PIU data and Operational excellence calculation/report (Evidence that the equipment is proven-in-use; Analysis of field failure rates to ensure that no systematic faults exist in the product)

[1] Type B component: "Complex" component (using micro controllers or programmable logic); for details see 7.4.3.1.3 of IEC 61508-2.

- A number of functional safety lifecycle assessment aspects are not required due to PIU assessment:
    - SRS
    - FSM Plan
    - Configuration management
    - Validation of development tools
    - Validation test plan
    - Architecture design
    - Integration and Unit test plans
    - Development process

4.2 Assessment level

The Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter has been assessed per IEC 61508 to the following levels:

- SIL 2 random integrity for single device (Hardware Fault Tolerance = 0)
- SIL 3 random integrity for multiple devices (Hardware Fault Tolerance = 1)

The development procedures were assessed according to PIU criteria as suitable for use in applications with a maximum Safety Integrity Level of 3 (SIL 3 capability) according to IEC 61508.

5 Results of the IEC 61508 Functional Safety Assessment

exida assessed a detailed Failure Modes, Effects, and Diagnostic Analysis (FMEDA) [R2] of the Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter to document the hardware architecture and failure behavior. The Safety Case created for the Eclipse Enhanced Model 705 3X documents this assessment.

exida assessed failure history of the Eclipse Enhanced Model 705 3X Guided Radar Level Transmitter see [D28] and performed a detailed analysis of the data provided, see [D27]. This PIU assessment is done in place of a detailed functional safety assessment for systematic failures. The Safety Case created for the Eclipse Enhanced Model 705 3X documents this assessment.

The requirements of SIL 3 have been met in this area.

5.1.1 Validation

Validation Testing results were reviewed via a set of documented tests (see [D2] and [D3]). As the Eclipse Enhanced Model 705 3X consists of simple electrical devices with a straightforward safety function, there is no separate integration testing necessary.

Procedures are in place for corrective actions to be taken when tests fail as documented in [D25].

Items from IEC **61508-2, Table B.3** include functional testing, project management, documentation, and black-box testing (for the considered devices this is similar to functional testing). Field experience and proven-in-use data are included for systematic capability. This meets SIL 3.

Items from IEC **61508-2, Table B.5** include functional testing and functional testing under environmental conditions, Interference surge immunity testing, fault insertion testing, project management, documentation, static analysis, dynamic analysis, and failure analysis, expanded functional testing and black-box testing. This meets SIL 3.

5.1.2 Modifications

Modifications are done per the Magnetrol International, Inc. Modification Procedures [D40] and [D41]. Impact Analyses are performed on changes to safety certified products. This meets SIL 3.

5.1.3 User documentation

Magnetrol International, Inc. created a Safety Manual for the Eclipse Enhanced Model 705 3X, see [D6]. This safety manual was assessed by *exida.* The final version is considered to be in compliance with the requirements of IEC 61508. The document includes all required reliability data and operations, maintenance, and proof test procedures.

The analysis shows that the Eclipse Enhanced Model 705 3X meets the systematic capability requirements of IEC 61508 SIL 3.

5.1.4 Update for Certification Renewal

Product changes made since the last certification [D48] were reviewed. A representative Impact Analysis [D57] and associated Validation Tests [D49] through [D53] were also reviewed.

The current revision of the schematics [D45], [D46] and [D47] were reviewed. The FMEDA did not need to change.

The Shipment [D42] and Field Return [D43] Records were reviewed and an actual field failure rate calculated. This was compared with the FMEDA calculations [R5] and found consistent.

The current revision of the Safety Manual [D54] was reviewed.

5.2 Hardware Assessment

To evaluate the hardware design of the Eclipse Enhanced Model 705 3X, a Failure Modes, Effects, and Diagnostic Analysis was performed by *exida*. This is documented in [R2]. The FMEDA was verified using Fault Injection Testing, see [D34].

A Failure Modes and Effects Analysis (FMEA) is a systematic way to identify and evaluate the effects of different component failure modes, to determine what could eliminate or reduce the chance of failure, and to document the system in consideration. An FMEDA (Failure Mode Effect and Diagnostic Analysis) is an FMEA extension. It combines standard FMEA techniques with extension to identify online diagnostics techniques and the failure modes relevant to safety instrumented system design.

From the FMEDA, failure rates are derived for each important failure category. Table 2 lists these failure rates separately for each output type as reported in the FMEDA reports. The failure rates are valid for the useful life of the devices. Table 3 lists sample PFD_{AVG} results.

Table 2 Failure rates according to IEC 61508

Device	λ_{sd}	λ_{su} [2]	λ_{dd}	λ_{du}	SFF
Eclipse Enhanced Model 705, 705-51A*-***, Low Trip	0 FIT	600 FIT	847 FIT	154 FIT	90.4%
Eclipse Enhanced Model 705, 705-51A*-***, High Trip	0 FIT	624 FIT	847 FIT	130 FIT	91.9%

Table 3 Sample PFD_{AVG} Results

Device	Proof Test Coverage	PFD_{AVG}	% of SIL 2 Range
Eclipse Enhanced Model 705 3X, 705-51A*-***	94%	1.06E-03	10.6%

For low demand SIL 2 applications, the PFD_{AVG} value of the Safety Instrumented Function needs to be ≥ 10^{-3} and < 10^{-2}. The FMEDA report [R2] lists the percentage of this budget that the Eclipse Enhanced Model 705 3X uses. Considering a proof test is performed every year, the Eclipse Enhanced Model 705 3X model uses 10.6% of the PFD_{AVG} budget.

These results must be considered in combination with PFD_{AVG} of other devices of a Safety Instrumented Function (SIF) in order to determine suitability for a specific Safety Integrity Level (SIL). The Safety Manual states that the application engineer should calculate the PFD_{AVG} for each defined safety instrumented function (SIF) to verify the design of that SIF.

[2] It is important to realize that the “no effect” failures are included in the “safe undetected” failure category according to IEC 61508. Note that these failures on their own will not affect system reliability or safety, and should not be included in spurious trip calculations

The architectural constraints requirements of IEC 61508-2, Table 2, are also reviewed. The Safe Failure Fractions (SFF) for both Eclipse Enhanced Model 705 3X configurations are greater than 90%. Therefore the Eclipse Enhanced Model 705 3X can be used in SIL 2 applications, in simplex (single device, HFT = 0) mode and SIL 3 applications in redundant (multiple devices, HFT = 1) mode.

The analysis shows that the design of the Eclipse Enhanced Model 705 3X meets the hardware requirements of IEC 61508 SIL 2, single device (HFT = 0) and SIL 3, multiple devices (HFT = 1).

Terms and Definitions

Fault tolerance	Ability of a functional unit to continue to perform a required function in the presence of faults or errors (IEC 61508-4, 3.6.3)
FIT	Failure In Time ($1x10^{-9}$ failures per hour)
FMEDA	Failure Mode Effect and Diagnostic Analysis
HFT	Hardware Fault Tolerance
Low demand mode	Mode, where the frequency of demands for operation made on a safety-related system is no greater than one per year and no greater than twice the proof test frequency.
PFD_{AVG}	Average Probability of Failure on Demand
PIU	Proven-In-Use
SFF	Safe Failure Fraction summarizes the fraction of failures, which lead to a safe state and the fraction of failures which will be detected by diagnostic measures and lead to a defined safety action.
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
SIS	Safety Instrumented System – Implementation of one or more Safety Instrumented Functions. A SIS is composed of any combination of sensor(s), logic solver(s), and final element(s).
HART	Highway Addressable Remote Transducer
Type B (sub)system	“Complex” (sub)system (using micro controllers or programmable logic); for details see 7.4.4.1.3 of IEC 61508-2

6 Status of the document

6.1 Liability

exida prepares reports based on methods advocated in International standards. Failure rates are obtained from a collection of industrial databases. *exida* accepts no liability whatsoever for the use of these numbers or for the correctness of the standards on which the general calculation methods are based.

6.2 Releases

Version: V1

Revision: R4

Version History:	V0, R1:	Internal Draft; 15 July, 2011
	V1, R1:	ready to release, but changed SIL after final review
	V1, R2:	changed p4 and p11 to clarify the restriction on the safety critical portion only
	V1, R3:	released, 5 Aug 2011
	V1, R4:	updated for re-certification, Q14/09-060; Griff Francis, 5 Dec 2014

Author:	Griff Francis	
Review:	V0, R1:	Rudolf Chalupa
	V1, R1:	Rudolf Chalupa
	V1, R4:	Rudolf Chalupa
Release status:	Released to Customer	

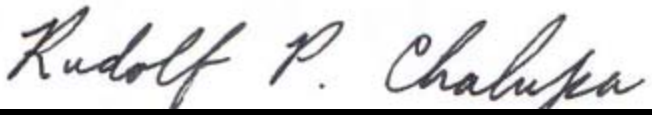
6.3 Future Enhancements

At request of client.

6.4 Release Signatures

Griff Francis, Senior Safety Engineer

John Yozallinas, Senior Safety Engineer



Rudolf Chalupa, Senior Safety Engineer