Results of the IEC 61508 Functional Safety Assessment

Project:
3051S Electronic Remote Sensors (ERS™) System

Customer:
Rosemount, Inc.
(an Emerson Process Management company)
Chanhassen, MN
USA

Contract No.: Q13/10-107
Report No.: ROS 13-10-107 R001
Version V1, Revision R2, November 19, 2014
Dave Butler

Management Summary

The Functional Safety Assessment of the Rosemount, Inc.

3051S Electronic Remote Sensors (ERS™) System

development project, performed by *exida* consisted of the following activities:

- *exida* assessed the development process used by Rosemount, Inc. through an audit and review of a detailed safety case against the *exida* certification scheme which includes the relevant requirements of IEC 61508. The investigation was executed using subsets of the IEC 61508 requirements tailored to the work scope of the development team.
- *exida* reviewed and assessed a detailed Failure Modes, Effects, and Diagnostic Analysis (FMEDA) of the devices to document the hardware architecture and failure behavior.
- *exida* reviewed field failure data to verify the accuracy of the FMEDA analysis.
- *exida* reviewed the manufacturing quality system in use at Rosemount, Inc..

The functional safety assessment was performed to the requirements of IEC 61508: ed2, 2010, SIL 3. A full IEC 61508 Safety Case was reviewed, using the *exida* Safety Case tool, which was used as the primary audit tool. Hardware process requirements and all associated documentation were reviewed. Environmental test reports were reviewed. Also the user documentation (safety manual) was reviewed.

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

The audited development process as tailored and implemented by the Rosemount, Inc. 3051S Electronic Remote Sensors (ERS™) System development project, complies with the relevant safety management requirements of IEC 61508 SIL 3.

The assessment of the FMEDA, done to the requirements of IEC 61508, has shown that the 3051S Electronic Remote Sensors (ERS™) System can be used in a low demand safety related system in a manner where the calculated PFD_{AVG} is within the allowed range for SIL 2 (HFT = 0) or SIL 3 (HFT = 1), according to table 2 of IEC 61508-1.

This means that the 3051S Electronic Remote Sensors (ERS™) System is capable for use in SIL 2 and SIL 3 applications in Low Demand mode, when properly designed into a Safety Instrumented Function per the requirements in the Safety Manual and when using the versions specified in section 3.1 of this document.

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

Table of Contents

1 Purpose and Scope

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

- 3051S ERS™ System

by *exida* according to the requirements of IEC 61508: ed2, 2010.

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

- the 3051S ERS™ System with the technical IEC 61508-2 and -3 requirements for SIL 3 and the derived product safety property requirements

  and

- the 3051S ERS™ System development processes, procedures and techniques, as implemented in the safety-related deliverables, with the IEC 61508-1, -2 and -3 functional safety management requirements for SIL 3.

  and

- the 3051S ERS™ System 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 *exida's* quality procedures and scope definitions.

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 avoidance and control of systematic failures during the development and manufacture 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.

The assessment was planned by *exida* and agreed with Rosemount, Inc..

All assessment steps were continuously documented by *exida* (see [R1])

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 certification, 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

Rosemount, Inc.	Manufacturer of the 3051S ERS™ System
exida	Performed the hardware assessment
exida	Performed the Functional Safety Assessment per *exida's* accredited scheme.

Rosemount, Inc. contracted *exida* with the IEC 61508 Functional Safety Assessment of the above mentioned devices.

2.3 Standards / Literature used

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

N1	IEC 61508 (Parts 1 - 7): 2010	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems

2.4 Reference documents

2.4.1 Documentation provided by Rosemount, Inc.

Doc. ID	Document
D001	Quality Manual
D003	Overall Development Process
D004	Configuration Management Process - 3051S ERS System specific
D004b	Configuration Management Process - Emerson Process
D005	Field Failure Reporting Procedure
D006	Field Return Procedure
D007	Manufacturer Qualification Procedure
D008	Part Selection Procedure - Supplier Quality Manual
D008b	Part Selection Procedure - ECO process
D010	Quality Management System (QMS) Documentation Change Procedure
D010b	Quality Management System (QMS) Documentation Change Procedure
D012	Non-Conformance Reporting procedure
D012b	Non-Conformance Reporting procedure
D012c	Non-Conformance Reporting procedure
D012d	Non-Conformance Reporting procedure - In process NC
D013	Corrective Action Procedure
D013b	Corrective Action Procedure - Supply Chain Corrective Action
D016	Action Item List Tracking Procedure
D019	Customer Notification Procedure
D021	Software Development Process
D021b	Software Tool Qualification Procedure
D023	Modification Procedure
D023b	Impact Analysis Template
D026	FSM Plan or Development Plan
D027	Configuration Management Plan
D029	Verification Plan
D030	Shipment Records
D031	Field Returns Records
D038	List of Design Tools
D040	Safety Requirements Specification
D041	Safety Requirements Review Record
D043	Software Safety Requirements Specification
D045	System Architecture Design Specification
D049	High Level Software Design Specification

D054	Verification Results
D054b	Verification Results - Example of Action Item follow up
D056	Requirements Traceability Matrix
D059	Fault Injection Test Plan
D060	Coding Standard
D069	Validation Test Plan
D070	Validation Test Plan Review Record
D071	Environmental Test Plan
D072	EMC Test Plan
D074	Validation Test Results
D075	Environmental Test Results
D076	EMC Test Results
D076b	EMC Test Results - Intertek report
D077	Fault Injection Test Results
D078	Operation / Maintenance Manual
D079	Safety Manual
D080	Safety Manual Review Record
D081	Engineering Change Documentation
D083	PIU Analysis
D084	Safety Case Workbook
D088	Impact Analysis Record

2.4.2 Documentation generated by *exida*

[R1]	Q1310-107 - Safety Case WB-61508 V1R4 - 3150S ERS	Safety Case
[R2]	ROS 13-10-107 R001 V1R2 61508 Assessment 3051S ERS	Assessment Report (this document)
[R3]	ROS 10-04-083 R001 V2R4 FMEDA 3051S ERS	FMEDA Report for the 3051S ERS System
[R4]	ROS 13-10-107 R002 V1R1 Safety Communications Analysis ERS	Communications Analysis Report

2.5 Assessment Approach

The certification audit was closely driven by requirements of the *exida* scheme which includes subsets filtered from IEC 61508.

The assessment was planned by *exida* and agreed with Rosemount, Inc..

The following IEC 61508 objectives were subject to detailed auditing at Rosemount, Inc.:

- FSM planning, including
    - Safety Life Cycle definition

    - Scope of the FSM activities
    - Documentation
    - Activities and Responsibilities (Training and competence)
    - Configuration management
    - Tools and languages
- Safety Requirement Specification
- Change and modification management
- Software architecture design process, techniques and documentation
- Hardware architecture design - process, techniques and documentation
- Hardware design / probabilistic
- System and hardware related V&V activities including documentation and verification
    - Integration and fault insertion test strategy
- Software related V&V activities including documentation and verification
- System Validation including hardware and software validation
- Hardware-related operation, installation and maintenance requirements

3 Product Description

The 3051S ERS™ System is a two wire, 4 – 20 mA architecture that calculates differential pressure electronically using two pressure transmitters (primary and secondary) that are linked together with a digital cable. The transmitter system uses standard, well-proven sensor boards in combination with a microprocessor board that performs diagnostics. It is programmed to send its output to a specified failure state, either high or low, when an internal failure is detected.

The bus between the current output microprocessor and the sensor microprocessor has been extended outside the transmitter housing to a second sensor microprocessor with its own housing.

It is assumed that the 4 – 20 mA output is used as a primary safety variable. No other output variants are covered by this report.

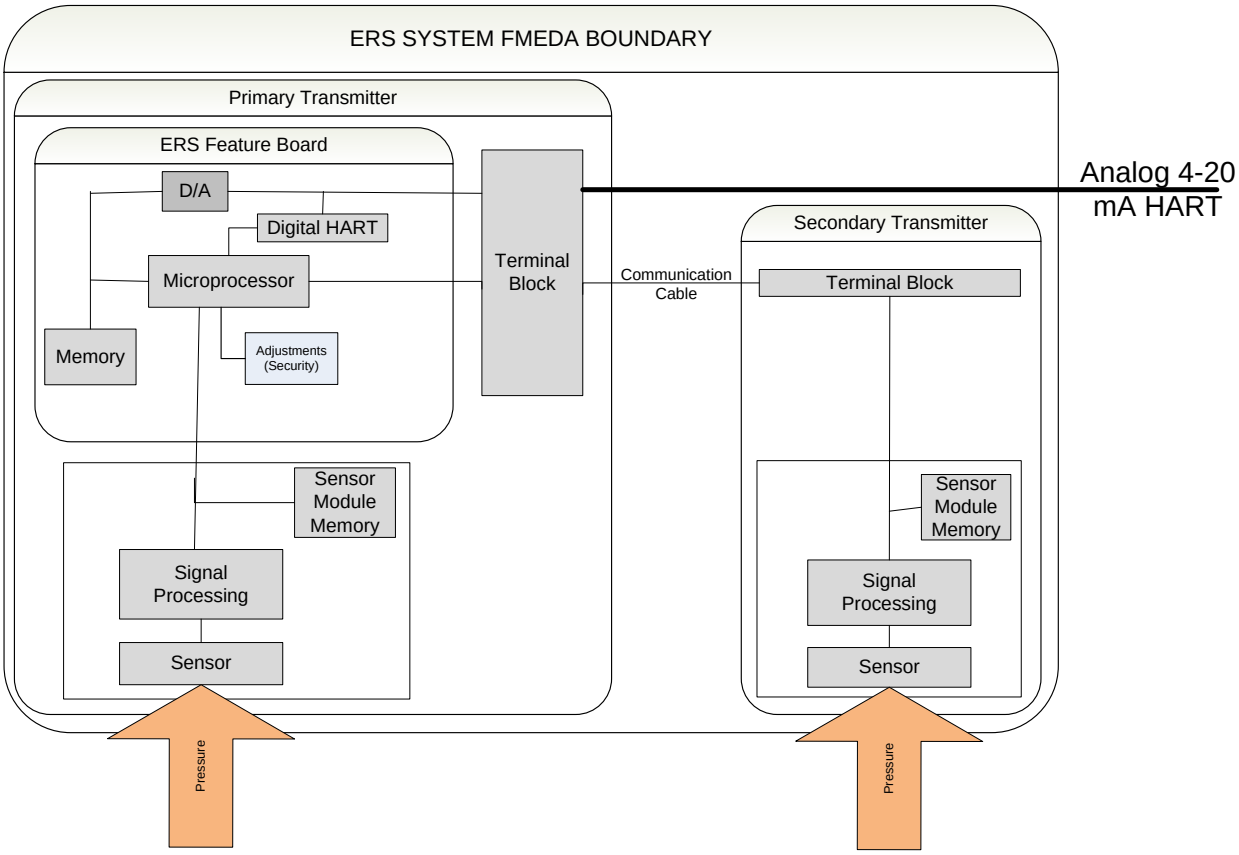


Figure 1 3051S ERS™ System, Parts included in the FMEDA

3.1 Software Version Numbers

This assessment is applicable to the following hardware and software versions of 3051S ERS™ System:

Model	Software Versions
3051SAL_P	Rev. 57 and above
3051SAL_S	Rev. 57 and above
3051SAM_P	Rev. 57 and above
3051SAM_S	Rev. 57 and above

4 IEC 61508 Functional Safety Assessment

exida assessed the processes used by Rosemount, Inc., and the engineering work products from those processes, related to the 3051S ERS™ System, in accordance with the objectives of the *exida* certification scheme and the requirements of the IEC 61508 standard. The results of the assessment are documented in [R1].

exida assessed the safety case, which includes documentary evidence, and argues how that evidence demonstrates compliance with the functional safety requirements in IEC 61508 standard. The safety case was created through an assessment of the documentation with respect to the requirements of the IEC 61508 standard. A second, certifying assessment of the safety case was carried out by a second, independent assessor.
The safety case documents the fulfillment of the functional safety requirements of IEC 61508-1 to 3. This assessment report summarizes those findings.

The assessment was carried out, in accordance with exida's certification scheme, which identifies all IEC 61508 standard requirements pertinent to the product's certification, and tailors the assessment to that scope.

The result of the assessment shows that the Product is capable for use in SIL 3 applications, when used properly in a Safety Instrumented Function by adhering to the instructions and constraints found in the 3051S ERS™ System Safety Manual [D079].

4.1 Product Modifications

The modification process has been successfully assessed and audited, so Rosemount, Inc. may make modifications to this product as needed.

As part of the *exida* scheme, a surveillance audit is conducted every 3 years. The modification documentation listed below is submitted as part of the surveillance audit. *exida* will review the decisions made by the competent person in respect to the modifications made.

- List of all anomalies reported
- List of all modifications completed
- Safety impact analysis which shall indicate, with respect to the modification:
  - The initiating problem (e.g. results of root cause analysis)
  - The effect on the product / system
  - The elements/components that are subject to the modification
  - The extent of any re-testing required
- List of modified documentation
- Regression test plans

5 Results of the IEC 61508 Functional Safety Assessment

exida assessed the development process used by Rosemount, Inc. during the product development against the objectives of the *exida* certification scheme which includes IEC 61508 parts 1, 2, & 3 see [N01]. The development of the 3051S ERS™ System was done per this IEC 61508 SIL 3 compliant development process. The Safety Case was updated with project specific design documents.

5.1 Lifecycle Activities and Fault Avoidance Measures

Rosemount, Inc. has an IEC 61508 compliant development process as assessed during the IEC 61508 certification. This compliant development process is documented in [D003].

This functional safety assessment investigated the compliance with the requirements of the IEC 61508 standard, of the processes, procedures and techniques, used in product development. The investigation was carried out using the *exida* certification scheme, which includes subsets of IEC 61508 requirements tailored to the SIL 3 work scope of the development team. The result of the assessment can be summarized by the following observations:

The audited development process complies with the relevant managerial requirements of IEC 61508 SIL 3.

5.1.1 Functional Safety Management

FSM Planning

The functional safety management of any Rosemount, Inc. Safety Instrumented Systems Product development is governed by [D003]. This process requires that Rosemount, Inc. create a project plan [D026] which is specific for each development project. The Project Plan defines all of the tasks that must be done to ensure functional safety as well as the person(s) responsible for each task. These processes and the procedures referenced herein fulfill the requirements of IEC 61508 with respect to functional safety management.

Version Control

All documents are under version control as required by [D027].

Training, Competency recording

Competency is ensured by the creation of a competency and training matrix as required by [D003]. The matrix lists all of those on the project who are working on any of the phases of the safety lifecycle. Specific competencies for each person are listed on the matrix which is reviewed by the project manager. Any deficiencies are then addressed by updating the matrix with required training for the project.

5.1.2 Safety Requirements Specification and Architecture Design

As defined in [D003] a system requirements document is created for all products that must meet IEC 61508 requirements. For the 3051S ERS™ System, the System Requirements Document [D040] contains a system overview, safety assumptions, constraints, dependencies, and safety requirements sections.

The Product Architecture Design, documented in the System Requirements Document [D040], was assessed and was found to comply with the relevant SIL 3 requirements of the IEC 61508 standard.

5.1.3 Software Architecture Design

The Software Architecture Design [D045] was reviewed to ensure that it can be used to guide modifications of the product. The Software Architecture Design documentation was found to adequately meet the relevant SIL 3 requirements of the IEC 61508 standard.

5.1.4 Validation

Validation Testing is done via a set of documented tests. The validation test cases, documented in a test specification [D069], are traceable to the safety requirements in the System Requirements Document [D040]. Traces are used to verified that all requirements are tested, by comparing all safety requirements references from the test specification to the list of safety requirements in the System Requirements Document shows that all safety requirements have been validated by one or more validation test cases. In addition to functional testing, third party testing is included as part of the validation plan. All non-conformities uncovered during Validation Testing are documented in change request documentation. Procedures are in place for corrective actions to be taken when tests fail as required by [D003].

Requirements from IEC **61508-2, Table B.5** that have been met by Rosemount, Inc. include functional testing, 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.

Requirements from IEC **61508-3, Table A.7** that have been met by Rosemount, Inc. include process simulation, functional and black box testing. This meets SIL 3 requirements.

5.1.5 Verification

Verification activities are built into the standard development process as defined in [D003], and include the following: Fault Injection Testing, static source code analysis, integration testing, FMEDA, peer reviews and both hardware and software unit testing. In addition, safety verification checklists are filled out for each required phase of the safety lifecycle. This meets the requirements of IEC 61508 SIL 3.

Requirements from **IEC 61508-2, Table B.3** that have been met by Rosemount, Inc. include functional testing, project management, documentation, and black-box testing.

Requirements from **IEC 61508-3, Table A.5** that have been met by Rosemount, Inc. include dynamic analysis and testing, data recording and analysis, functional and black box testing, performance testing, interface testing, and test management and automation tools.

Requirements from **IEC 61508-3, Table A.6** that have been met by Rosemount, Inc. include functional and black box testing, performance testing, and forward traceability between the system and software design requirements for hardware/software integration and the hardware/software integration test specifications

Requirements from **IEC 61508-3, Table A.9** that have been met include static analysis, dynamic analysis and testing, forward traceability between the software design specification and the software verification plan.

This meets the requirements of SIL 3.

5.1.6 Modifications

Modifications are done per the Rosemount, Inc.'s change management process as documented in [D023] and [D023b]. Impact analyses are performed for all changes once the product is released to production. The results of the impact analysis are used in determining whether to approve the change. The Modification Procedure [D023] is followed and the standard development process is re-entered at the phase specified by the Impact Analysis record, limiting the scope of verification and validation as directed by the Impact Analysis record. The handling of hazardous field incidents and customer notifications is governed by [D083] and [D019}. This procedure includes identification of the problem, analysis of the problem, identification of the solution, and communication of the solution to the field. This meets the requirements of IEC 61508 SIL 3.

Requirements from **IEC 61508-3, Table A.8** that have been met by the Rosemount, Inc. modification process include impact analysis, reverify changed software modules, reverify affected software modules, revalidate complete system or regression validation, software configuration management, data recording and analysis, and forward and backward traceability between the software safety requirements specification and the software modification plan (including reverification and revalidation)

5.1.7 User documentation

Rosemount, Inc. created a safety manual for the 3051S ERS™ System [D079] which addresses all relevant operation and maintenance requirements from IEC 61508, and contains safety information which facilitates the proper inclusion of the 3051S ERS™ System into a safety system application. This safety manual was assessed by *exida*. The final version is considered to be in compliance with the requirements of IEC 61508.

Requirements from IEC **61508-2, Table B.4** that have been met by Rosemount, Inc. include operation and maintenance instructions, maintenance friendliness, project management, documentation, and limited operation possibilities.

This meets the requirements for SIL 3.

5.2 Hardware Assessment

To evaluate the hardware design of the 3051S Electronic Remote Sensors (ERS™) System, a Failure Modes, Effects, and Diagnostic Analysis was performed by *exida* for each component in the system. The FMEDA was verified using Fault Injection Testing as part of the development and as part of the IEC 61508 assessment.

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.

Failure rates are listed in the FMEDA reports for each important failure category. Refer to the FMEDA [R3] for a complete listing of the assumptions used and the resulting failure rates.

The FMEDA results must be considered in combination with PFD_{AVG} and architectural constraints 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.

The FMEDA analysis shows that 3051S ERS™ System has a Safe Failure Fraction > 90% and therefore, it meet Route 1_H hardware architectural constraints for up to SIL 2 as a single device.

If the 3051S ERS™ System is one part of an element the architectural constraints should be determined for the entire sensor element

The 3051S ERS™ System is a Type B device. The required SIL determines the level of hardware fault tolerance that is required per requirements of IEC 61508 or IEC 61511. The SIS designer is responsible for meeting other requirements of applicable standards for any given SIL as well.

The analysis shows that design of the Rosemount 3051S ERS™ System meets the hardware requirements of IEC 61508, SIL 2 @HFT=0 and SIL 3 @ HFT=1.

6 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 demand interval for operation made on a safety-related system is greater than twice the proof test interval.
PFD_{AVG}	Average Probability of Failure on Demand

PFH	Probability of dangerous Failure per Hour
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
AI	Analog Input
AO	Analog Output
DI	Digital Input
DO	Digital Output
Type A element	“Non-Complex” element (using discrete components); for details see 7.4.4.1.2 of IEC 61508-2
Type B element	“Complex” element (using complex components such as micro controllers or programmable logic); for details see 7.4.4.1.3 of IEC 61508-2

7 Status of the document

7.1 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.

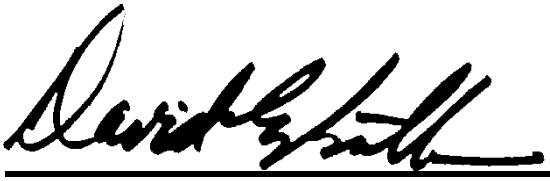
7.2 Releases

Version History:	V1, R2:	Updated revision of the Comm. Analysis Report; DEB – 11/19/2014
	V1, R1:	Updated based on Rosemount comments; DEB – 10/21/2014
	V1, R0:	Initial version; DEB – 9/30/2014
Authors:	Dave Butler	
Review:		
Release status:	RELEASED	

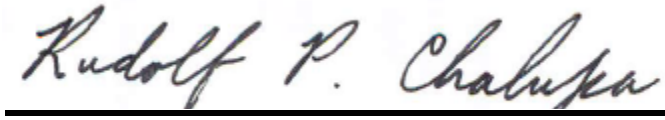
7.3 Future Enhancements

At request of client.

7.4 Release Signatures



David Butler, CFSE, Safety Engineer



Rudolf P. Chalupa, Senior Safety Engineer