NETWORK MANAGEMENT AND FDIR FOR SPACEWIRE NETWORKS

N-MaSS/FDIR – Executive Summary

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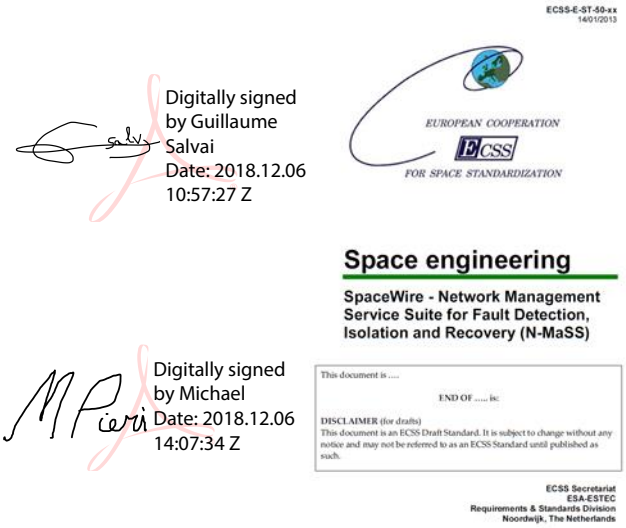
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14/01/2013

EUROPEAN COOPERATION ECSS FOR SPACE STANDARDIZATION

Space engineering

SpaceWire - Network Management Service Suite for Fault Detection, Isolation and Recovery (N-MaSS)

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CHANGE RECORD

Issue	Revision	Date	Section and Page	Reason for Change
1	0	05.11.2018	All	Creation of the document

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1 SCOPE

The objective of this document is to provide a summarised description of the various outcomes at the end of the ESA study untitled **"Network Management Service Suite – NMaSS"**. The project context, phases and objectives are described in section 2, followed by an overview of the final results based on the built demonstrator.

1.1 APPLICABLE DOCUMENTS

The following documents shall be applicable to the activity:

[AD 1]	ITT AO/1-7003/11/NL/LvH	"Invitation to Tender: Network Management and FDIR for SpaceWire Networks"
[AD 2]	SoW AO/1-7003/11/NL/LvH	"Statement of Work: Network Management and FDIR for SpaceWire Networks"

1.2 REFERENCE DOCUMENTS

The following documents are reference documents:

[RD 1]	ASG7.TP.1843.ASTR	"NMASS – Technical Proposal", v1.0, 01/02/2012
[RD 2]	ECSS-E-ST-50-12C	"SpaceWire – Links, Nodes, Routers and Networks", ECSS Standard, 31/07/2008
[RD 3]	NMASS.1843.TN.001.ASU	"D1 NMASS – User Requirements Document", v1.0, 29/01/2013
[RD 4]	NMASS.1843.TN.002.ASU	"D2 NMASS – Demonstrator Architectural Design", v1.0, 29/01/2013
[RD 5]	ECSS-E-ST-50-xx	"D3 NMASS – SpaceWire: Network Management Service Suite for Fault Detection, Isolation and Recovery (N-MaSS)", ECSS Standard Draft, 14/01/2013
[RD 6]	NMASS.1843.TN.004.ASU	"D4 NMASS – Demonstrator Specification", v1.0, 29/01/2013
[RD 7]	NMASS.1843.TN.005.ASU	"D5 NMASS – Verification Procedures", v1.0, 29/01/2013
[RD 8]	NMASS.1843.TN.005.ASU	"Design and Inspection & Verification Test Cases", 4Links, v4.0, 21/03/2014
[RD 9]	NMASS.1843.TN.006.ASU	"D6 NMASS – Design and Inspection & Verification Test Cases for the Node Component", 4Links, v9.0, 18/01/2015
[RD 10]	NMASS.1843.TN.007.ASU	"D7 NMASS – Design and Inspection & Verification Test Cases for the Routing Switch Component", 4Links, v9.0, 18/01/2015
[RD 11]	NMASS.1843.TN.008.ASU	"D8 NMASS – Demonstration and Validation Report", v2.1, 15/10/2018
[RD 12]	NMASS.1843.TN.009.ASU	"D9 NMASS – Final Report", v1.0, 15/10/2018

1.3 ACRONYMS AND ABBREVIATIONS

AD	**A**pplicable **D**ocument
BER	**B**it **E**rror **R**ate

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BSP	**B**oard **S**upport **P**ackage
BSU	**B**enchmark **S**upport **U**nit
CCSDS	**C**onsultative **C**ommittee for **S**pace **D**ata **S**ystems
EGSE	**E**lectrical **G**round **S**upport **E**quipment
ESA	**E**uropean **S**pace **A**gency
ESTEC	**E**uropean **S**pace Research and **Te**chnology **C**entre
FDIR	**F**ault **D**etection **I**solation and **R**ecovery
FPGA	**F**ield **P**rogrammable **G**ate **A**rray
GUI	**G**raphical **U**ser **I**nterface
HS	**H**ealth **S**tatus
HW	**H**ard**w**are
IDE	**I**ntegrated **D**evelopment **E**nvironment
I/F	**I**nter**f**ace
I/O	**I**nput / **O**utput
JTAG	**J**oint **T**est **A**ction **G**roup
MTBF	**M**ean **T**ime **B**etween **F**ailures
MIPS	**M**illions of **I**nstructions **P**er **S**econd
N/A	**N**ot **A**pplicable
NMASS	**N**etwork **M**anagement **S**ervice **S**uite
OS	**O**perating **S**ystem
OSI	**O**pen **S**ystem **I**nterconnection
PCB	**P**rinted **C**ircuit **B**oard
SDE	**S**oftware **D**evelopment **E**nvironment
SEE	**S**ingle **E**vent **E**ffect
SEU	**S**ingle **E**vent **U**pset
SMU	**S**pacecraft **M**anagement **U**nit
SoW	**S**tatement **O**f **W**ork
SpW	**Sp**ace**W**ire
SS	**S**un **S**ensor
STR	**S**tar **T**racker
SW	**S**oft**w**are

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2 PROJECT OVERVIEW

2.1 CONTEXT

The SpaceWire standard (**[RD 2])** defines the aspects of a highly flexible and capable communication system with multiple point-to-point links and switching capabilities. It defines a number of features corresponding to the network layer of the OSI model, including a few error handling processes for link and time code errors. However, a standardised approach for handling network management and autonomous FDIR functions for SpW-based systems is not available. The network management and FDIR aspects related to SpW networks must still be designed specifically for each application/mission, usually requiring customised software and/or hardware.

This is important for various types of missions and should be a priority axis for improvement in the future evolutions of the SpaceWire standard as it would allow for the rationalisation of spacecraft on-board firmware and software and would maximise re-use, reducing costs and improving the development and validation cycles.

The ESA study **'Network Management Service Suite' (N-MaSS)** for Fault Detection, Isolation and Recovery (FDIR) focuses on implementation and standardisation of FDIR functions within the SpaceWire network management layer, as shown in Figure 1.

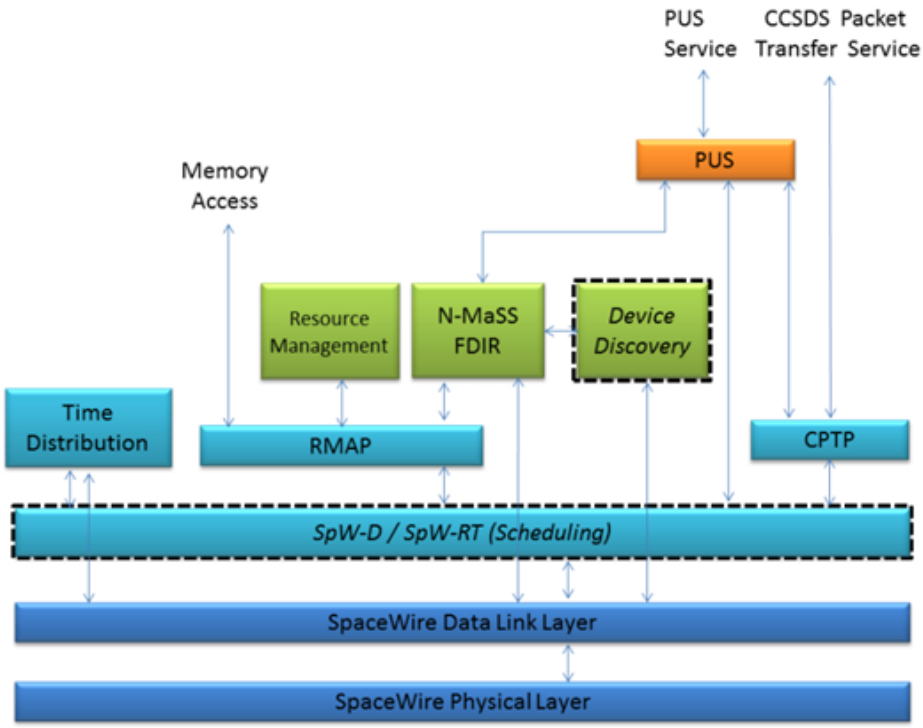

Figure 1: N-MaSS position in the SpaceWire Protocol Stack

The overall objective of the study is to provide a standardised FDIR service for SpW networks by means of:

- A protocol specification for the collection and handling of errors by a centralised authority on the network (SpW-FDIR);
- A protocol specification to configure SpW switches and nodes, to support the Isolation and Recovery services;
- A functionally partitioned architecture of the services to support the required FDIR functionality.

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2.2 CONSORTIUM

N-MaSS is an ESA project carried out by an industrial consortium composed of:

- *Airbus Ltd* (project prime),
- *4Links Ltd;* and
- *Teletel SA*.

The key responsibilities of each member of the consortium is detailed in Figure 2 below:

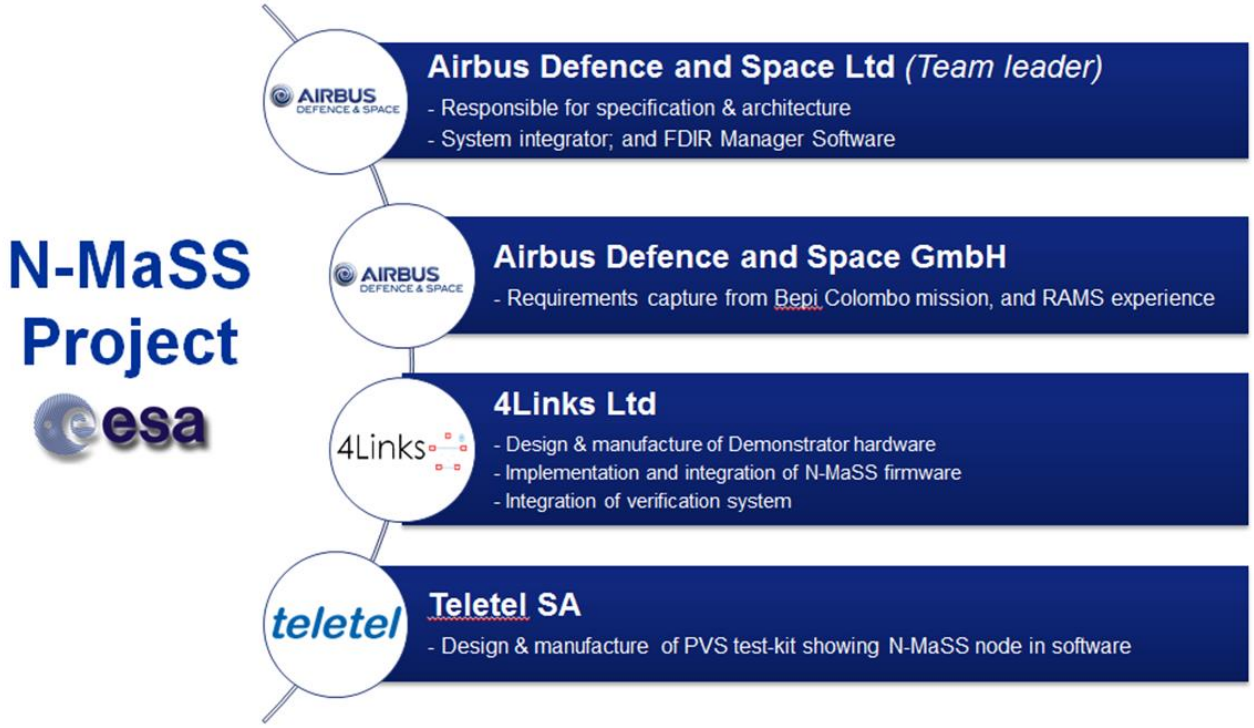

Figure 2: Consortium and Responsibilities

2.3 BUDGET

The total budget for this project was **€250K**, with the repartition as in Figure 3.

Company Name	Vendor Code	Type P/Prime; SI/Subco Indirect	Country (ISO Code)	Total Amount
Astrium Limited	1000004092	Prime	GB	€123,000
Astrium GmbH	1000003785	SI	DE	€12,000
4Links Ltd	1000001167	SI	GB	€85,000
Teletel SA	1000000090	SI	GR	€30,000

Figure 3: Budget per Company

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2.4 OBJECTIVES

The NMaSS study aimed at addressing the lack of FDIR features for SpW networks, and exploring the various possibility to tackle the problem and provide an autonomous FDIR solution.

This overall goal led to the following multiple phases, as shown in Figure 4:

- User Requirements gathering and analysis;
- Design of an FDIR innovative approach and solution;
- Verification of the NMaSS concept at breadboard level; and
- Final validation on a representative SpW network.

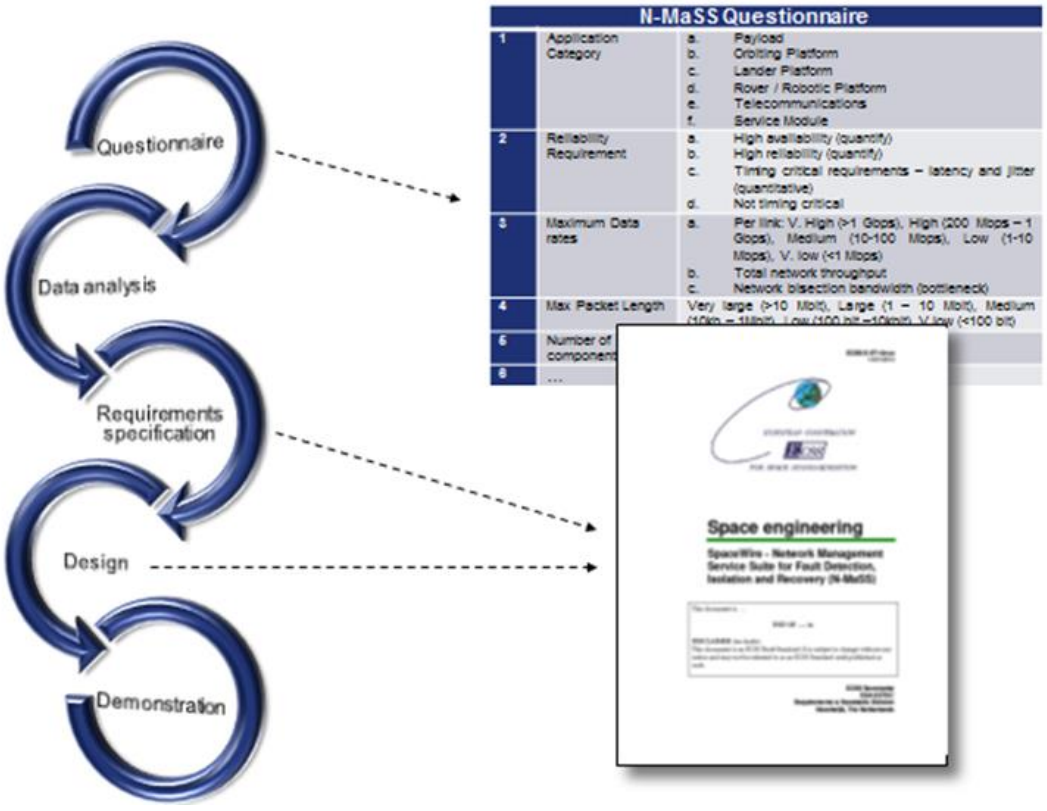

Figure 4: N-MaSS Study Phases

A key point to design the innovative N-MaSS service was to shaped it on the basis of requirements obtained from European, US and Japanese parties. Preliminary investigations revealed that the diversity of user requirements brought together from different industry sources would have made the requirements integration into a coherent whole particularly difficult. This issue was resolved by ensuring early, open discussions with stakeholders via clear and unambiguous questionnaires, and via consultation with the SpaceWire Working Group and ESA.

A technology demonstrator was developed and a draft extension to the European Cooperation for Space Standardisation (ECSS) SpW standard produced. The N-MaSS demonstrator aimed at being a *proof of concept* prototype technology, able to manage the network topology and configurations, integrate the SpW

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FDIR capabilities and show the maintained connectivity and performance of data handling networks in the presence of failures.

The various phases of the study, along with the corresponding project milestones and deliveries, are detailed in Figure 5 below.

Appendix 1 to
ESA Contract No. xxxxxxxxxx
Page 1

APPENDIX 1: PAYMENT PLAN AND ADVANCE PAYMENTS AND OTHER FINANCIAL CONDITIONS

Payment to Prime Contractor only (indirect payments to Subcontractors)

Milestone (MS) Description	Schedule Date	Payments from ESA to Prime Contractor	For Information: Payment amount to Contractor and Subcontractor(s)			
			Contractor Astrium Ltd	Subcontractor Astrium GmbH	Subcontractor 4Links Ltd	Subcontractor Teletel
Progress (MS 1): Upon successful completion of the User Requirements Review and acceptance of all related deliverables	January 2013	€112,550	€43,050	€12,000	€42,500	€15,000
Progress (MS 2): Upon successful completion of PM3 and acceptance of all related deliverables	August 2013	€95,850	€55,350	0	€25,500	€15,000
Final Settlement (MS 3): Upon the Agency's acceptance of all deliverable items due under the Contract and the Contractor's fulfilment of all other contractual obligations including submission of the Contract Closure Documentation	January 2014	€41,600	€24,600	0	€17,000	0
TOTAL		€250,000	€123,000	€12,000	€85,000	€30,000

Figure 5: N-MaSS Milestones and Payments

A summary of all the objectives is provided below.

Overall Goal:

- **Provide** ESA SpaceWire Network (and the worldwide SpaceWire community) with a SpaceWire Network Management Service Suite (N-MaSS) – focussing on **FDIR**.

First Objective:

- **Specify** a SpaceWire N-MaSS as a set of services allowing management of SpaceWire networks, with the focus on FDIR issues.
- **Produce** of a **draft ECSS standard (SpW-FDIR Protocol),** shaped on the basis of requirements obtained from European, US and Japanese parties.

Second Objective:

- **Implement** the specified SpaceWire Network Management Service Suite at breadboard level, and **verify** this implementation.

Third Objective:

- **Validate** the SpaceWire Network Management Service Suite on a **representative payload network demonstrator**.
- The N-MaSS demonstrator shall be a **proof of concept demonstrator** with the capabilities to simulate the relevant failure and show the reliable and performant fault-recovery mechanism.

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3 PROJECT OUTCOMES

3.1 SPW-FDIR CONCEPT

N-MaSS provides an autonomous FDIR service which continuously probes the network to verify whether the network connectivity is intact (by periodically pinging HS requests to each component and handling the HS responses), and whether the network is meeting its service guarantees in terms of throughput and latency. If any problems are detected, the service will diagnose which component or link is at fault; it will isolate the failed component or link, to prevent it from impacting the services provided on the rest of the network. Finally, the service will attempt to recover the component if possible; if this does not succeed, it will autonomously switch in redundant components or links to meet the network service guarantee. Given a network containing sufficient redundancy, the N-MaSS service suite provides a high-level reliability and availability guarantee at the system level.

To implement this FDIR strategy, a dedicated SpW-FDIR protocol has been designed and a draft ECSS standard produced. This protocol has been designed to be extremely fast response, lightweight and optimised for FDIR purposes.

Figure 6 below gives an overall picture of the SpW-FDIR concept.

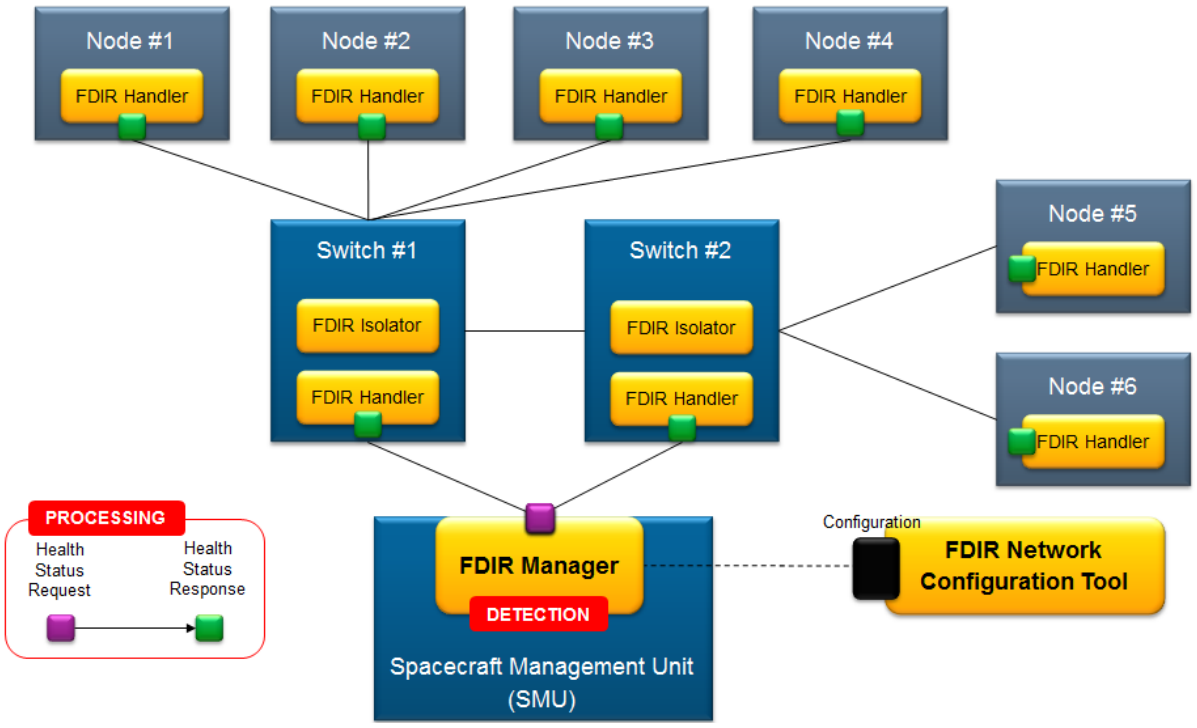

Figure 6: SpW-FDIR Concept

3.2 RESULTS

The NMaSS study has addressed all the initial objectives described in section §2.4:

- The draft ECSS standard clearly described the new SpW-FDIR protocol, based on Airbus experience and additional requirement inputs from other companies and agencies. Very few errors, inconsistencies, or required clarifications were found in the draft standard and it has proven to be remarkably clear to use by two independent implementers (Teletel in software and 4Links in firmware)

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- The verification validation phases have been a success, and the SpW-FDIR concept has been demonstrated on a representative final NMaSS demonstrator described in section 3.3. All the FDIR capabilities have been validated, and the study has been successful in developing and integrating a complete and representative system that includes a comprehensive implementation of FDIR.

3.3 N-MASS FINAL DEMONSTRATOR

The delivered demonstration system includes 40 SpaceWire links, 10 different functions implemented in FPGA firmware on a total of 24 4Links modular PCBs, together with 4 nodes simulated by software in a Teletel PVS/PC. The final SpW network topology is shown in Figure 7.

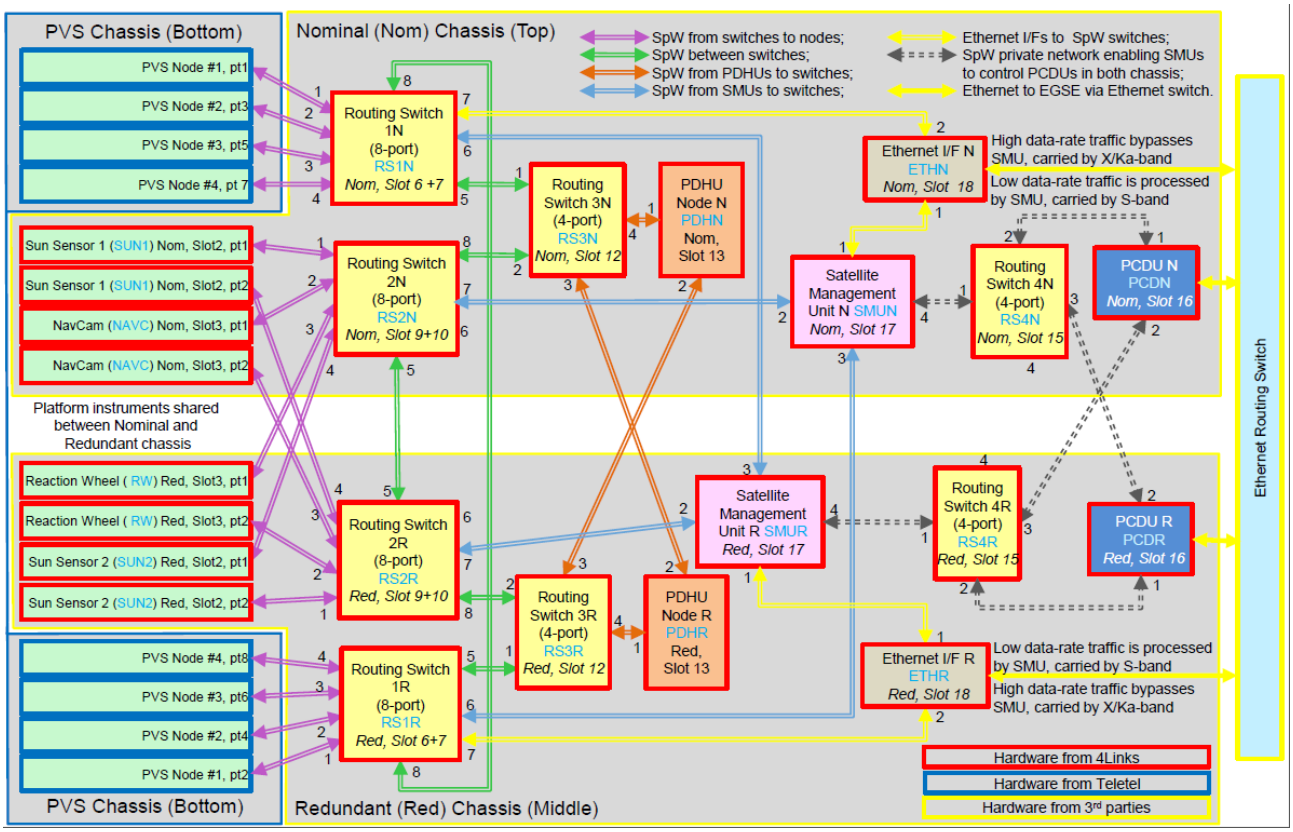

Figure 7: N-MaSS SpW Network Architecture

This SpW network is a representative fully-fledged network, which gathers eight instruments and 8-port switches, with multiple degrees of redundancy (Both at SpW interface and instrument level).

As shown on Figure 8, the N-MaSS demonstrator is divided into two chassis gathering the nominal and redundant hardware elements, with an additional rack-mount PC to host the “Instrument Simulator” iSAFT software.

Additionally, the final setup and EGSE application are provided in Figure 8 and Figure 9.

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Figure 8: N-MaSS Demonstrator Setup

Figure 9: N-MaSS Demonstrator (HW racks, EGSE and iSAFT)

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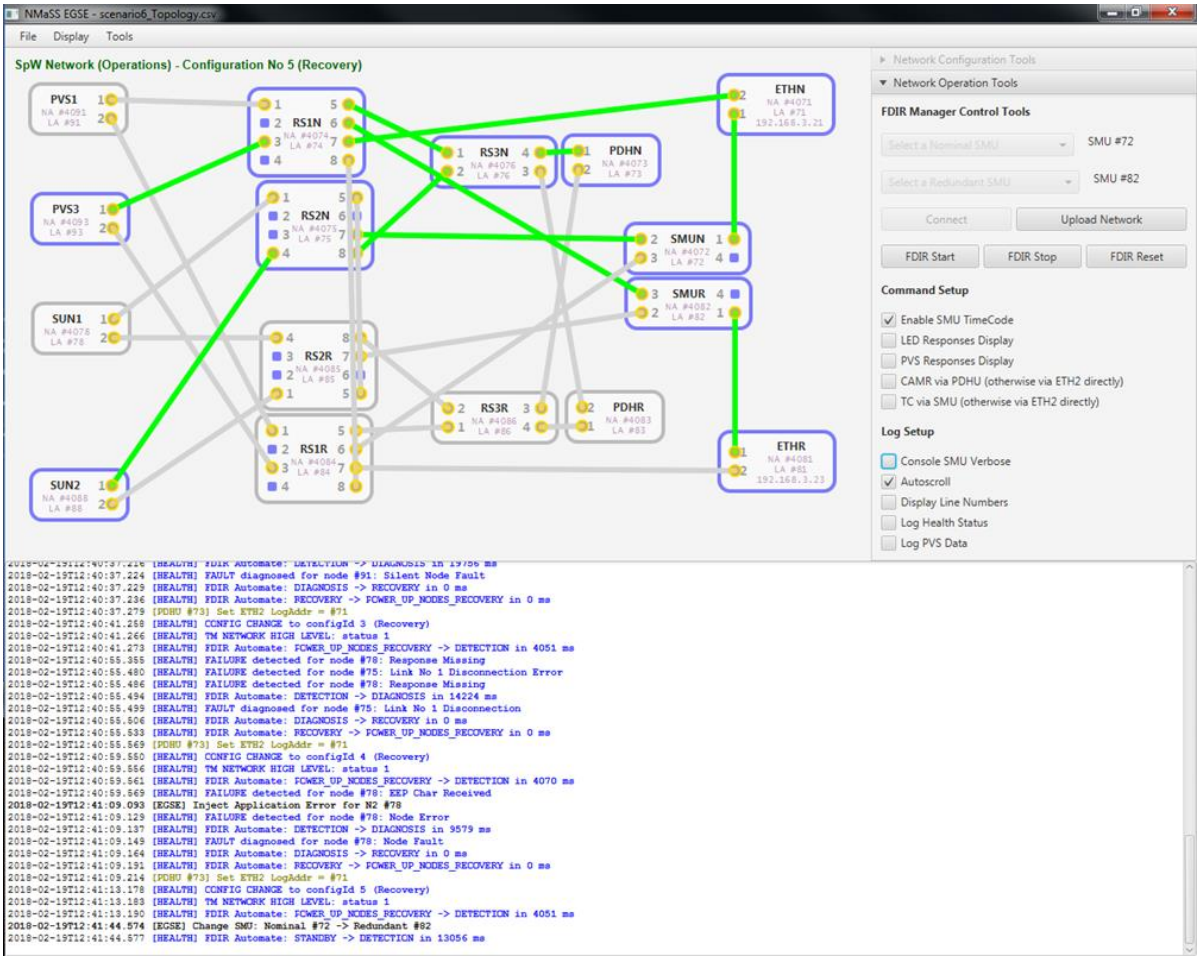

Figure 10: Example Scenario – EGSE

The N-MaSS demonstrator successfully implements the SpW-FDIR on a very representative SpW network, while meeting the initial user requirements in terms of FDIR capabilities and performance.

The main outcomes are summarised below:

- The FDIR Manager probing the SpW network is an efficient way to make the network more resilient and it works.
- The idea to keep the SpW network simple (with less but larger switches) shall prevail to successfully monitor the network and autonomously repair faults. The N-MaSS demonstrator – with a scalable number of components – highlights the complications when larger SpW networks are involved.
- The designed FDIR mechanism allowed to detect and repair a wide set of failures (which includes SMU hot redundancy, SpW links and node errors).
- The EGSE application is flexible to implement and configure any desired SpW network, with relevant parameters.

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4 FINAL CONCLUSIONS

4.1 SUMMARY

The N-MaSS study overall goal was to provide ESA (and the worldwide community) with a SpaceWire Network Management Service Suite focussing on FDIR. This objective has been fulfilled successfully, and the following key aspects achieved:

- User requirements have been gathered regarding the FDIR for SpW networks;
- A SpW-FDIR protocol has been designed and all the N-MaSS set of services specified;
- An ECSS draft standard has been produced accordingly;
- An N-MaSS demonstrator has been designed based on a representative SpW network to emphasise system-level issues;
- The resulting protocol has been successfully implemented in the final Network Management Service Suite (N-MaSS) demonstrator – both verified at breadboard level and validated at demonstrator level.

This N-MaSS prototype system is a proof of concept technology with the capabilities to simulate the relevant failure and show the reliable and performant fault-recovery mechanism, hence providing a solution for simplifying network management and autonomous network level fault detection, isolation and recovery. It handles a fully-fledged representative SpW network with up to eight instruments, addresses the lack of FDIR functionalities in the SpW standard and successfully demonstrates a number of system-level scenarios of its SpW-FDIR service. The SpW network connectivity and Quality of Service is shown to be autonomously maintained in the presence of many different types of failures. This is an extremely important step in the demonstration of the SpW-FDIR capabilities and benefits; highlighting a first level FDIR service that is reactive, autonomous and integrated within the network management function.

The N-MaSS system is an early architecture system; it relies on light weighted FDIR functions (Handler and Isolator) which leave all the networks configurations to the FDIR Manager authority. The number of instruments and SpW links achieved also highlight many system issues seen during the integration phase (e.g. contention, congestion), which is considered as a key part of the study outcomes.

4.2 WAY FORWARD

This initial NMaSS study was to design a new SpW-FDIR protocol and explore various possibilities to handle FDIR for large SpW networks. The final demonstrator does have some limitations, but highlights many FDIR issues. In doing so, it does – however – mix different categories of FDIR (i.e. SpW network, applications, power, SMU redundancy), which should now be distinguished and clarified. The next step would be to clarify those points and update the user requirements, define clearly what a SpW-FDIR should and shouldn't do, and go forward by building an improved system which taking advantages of both protocols SpW-FDIR and SpW-NDCP.

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