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Work Package Specification for the ODIN Instrument

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1. PROJECT GOAL, STRATEGIES

1.1 Background

Starting some 10 years ago, neutron imaging has seen a tremendous advance of existing techniques as well as the development of new imaging techniques. While some techniques are similar to, or based on, x-ray techniques they do provide complementary results. In addition to that, there are neutron imaging techniques that are unique i.e. no x-ray based equivalent exists.

With increasing spatial resolution, neutron imaging has become more flux-hungry. Emerging new techniques that require wavelength resolution via the time of flight technique require a reliable neutron-source timestructure. The ESS's approach of a pulsed source with longer (2.8 ms) pulses satisfies both needs; ESS is therefore in an ideal position to host a neutron imaging beamline.

1.2 Project Team

ODIN is a collaboration between ESS, PSI and TUM as lead institution. The financial distribution is currently set at roughly ESS: 8.9% PSI: 33.2%, TUM: 57.9%.[1]
The lead instrument scientist is responsible for coordinating the efforts between German (TUM), Swedish (ESS) and Swiss (PSI) contributions. Currently contributions from each country include a national lead scientist. TUM also supports the ODIN lead engineer. Scientific and administrative personnel at each institution support the project. As the project progresses, further personnel will be hired when needed.

1.3 Project Goal

The "Optical and Diffraction Imaging with Neutrons" beamline, the ODIN project, aims at providing a world class neutron imaging beamline that will offer or even define the state of the art in neutron imaging. The first and foremost goal is to create an imaging beamline that offers the opportunity for high resolution white beam imaging AND for wavelength resolution with unprecedented flexibility in both resolution and bandwidth.

1.4 General Project Strategies

Like most, if not all other neutron beamlines, ODIN as a whole consists of different subsystems (neutron extraction, guide and delivery, beam conditioning, detector system, etc.) that in turn consist of technical components. Each component must comply with safety requirements and together they must meet the functional requirements in order to satisfy the scientific requirements/needs.
In order to achieve this, the instrument team sets the requirements for subsystems and technical components if they do not follow directly from the high level

[1] The ESS contribution refers only to the defined Instrument scope and does not include costs for e.g. vacuum and other utilities and components provided by ESS.

requirements outlined in the ODIN Concept of operation [1]. Technical solutions will then be designed in close contact with appropriate ESS groups and discussed with other Neutron Imaging Groups if necessary. Designs may be discussed with potential vendors where unavoidable. Once the design is complete and approved (TG3), the instrument team will commence with the procurement, fabrication, installation and testing of the technical components. The technical components will be operated using the instrument infrastructure, which provides the utilities and the shielding necessary. Similar to the technical components, infrastructure will be designed by the instrument team in close contact with the ESS technical groups. Every step of this process will be communicated to appropriate ESS groups and management to ensure compliance with the ESS requirements.

1.5 Interfaces to other Projects or Assignments

The ODIN team is also part of Neutron Imaging groups at FRM-II (ANTARES, NECTAR) and PSI (ICON, NEUTRA and BOA); the team will draw from the experience in these groups especially for experimental set ups including detectors. Furthermore, the team will closely monitor and discuss developments at newly emerging Neutron Imaging beamlines at spallation sources (IMAT at ISIS, VENUS at SNS and RADEN at J-Parc) and plans to collaborate with these groups.

2. PROJECT SCOPE

2.1 Instrument Overview

As most other ESS beamlines, the ODIN instrument comprises three main subsystems: beam transport and conditioning system, sample exposure system and scattering characterization system (technically ODIN is not a scattering instrument but the nomenclature follows ESS rules ref. [2]). The three main subsystems fulfill the top level system requirements; they are shielded and supported by structures that house these subsystems and the software to control the instrument and process the data as described in the instrument product breakdown structure (PBS).

Beam transport and conditioning system (BTCS) (13.6.5.1)
The beam transport system extracts and transports neutrons from moderator to sample; size, divergence and wavelength spectrum and resolution of the beam are tailored to the needs of the experiment.

Sample exposure system (SES) (13.6.5.2)
The sample exposure system positions the sample in the neutron beam and controls the physical and chemical environment of the sample by utilizing various sample environment equipment (SEE). The choice of SEE is driven by the needs of the experiment.

Scattering characterization system (SCS) (13.6.5.3)
The purpose of this system is to detect neutrons transmitted through a sample, so that meaningful experimental data can be produced.[2]

Experimental cave (13.6.5.5)
The experimental cave hosts the beam defining elements of the BTCS and SES. It shields the surrounding hall from the radiation generated by these systems, as well as it protects the detector system from interference with an external radiation.

Control hutch (13.6.5.6)
The control hutch hosts the experiment control and data processing terminals. During an experiment the user team spends most of their time in the control hutch.

Sample preparation area (13.6.5.7)
The sample preparation area contains all the necessary equipment for the sample handling, mounting and storage between experiments. The clear separation between non- and irradiated sample storage areas will be imposed.

Utilities distribution (Infrastructure) (13.6.5.8)
Hall one contains all the shielding, utilities, infrastructure and support systems for the BTCS elements.

Support infrastructure (13.6.5.9)
Hall one contains all the infrastructure and support systems for the instrument components.

Control racks (13.6.5.10)
This system includes DAQ, DMSC, motion control, chopper control, vacuum control and PSS racks.

Integrated control and monitoring system (13.6.5.11)
The integrated control and monitoring system allows the user to control the experimental parameters and process the neutron data. It also contains the control and monitoring systems needed for the safe operation of the instrument.

3. WORK BREAKDOWN

3.1 Instrument Work Units

Work Units encompass all the deliverables a single responsible partner contributes to the instrument construction Work Package. There are three partners within in the ODIN Team that are responsible for delivering the instrument: ESS, PSI and TUM.

The work units and their responsible partner are summarized in Table 1 following the work breakdown structure used in the Scope Setting meeting:

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[2] Neutron Imaging is based on transmitted not scattered neutrons, we use “scattering system” here following ESS nomenclature.

01 Management	TUM
02 Neutron Transport	PSI
03 Heavy Shutter	ESS, TUM
04 T0 Chopper	ESS
05 Choppers	TUM
06 Cave Interior	PSI
07 Add ons (Instr. Specific Equipment)	ESS
08 Motion Control and EE	TUM
09 White beam detectors	PSI
10 ToF Detectors	ESS
11 Shielding	TUM
12 Instrument Infrastructure	TUM
13 Vacuum	ESS
14 PSS	TUM, ESS

Table 1. Work Unit Overview

The deliverables that compose the Work Units are indicated in the Work Breakdown Structure (WBS). Work Units are based on engineering- and environmental constraints. Individual Work Units may, therefore, not follow the PBS, i.e. one product can be spread over various Work Units as detailed below.[3]

3.1.1 Management WU (TUM)

Naturally, each partner is responsible for managing within own work units. Overall management and integration, however, falls into the responsibility of the lead institution, TUM; the related PBS item is:

13.6.5.0 ODIN Instrument Integration

3.1.2 Neutron Transport (PSI)

The neutron transport system extracts and transports a neutron beam from the moderator all the way to the cave. The system includes interfaces with the monolith, floors, bunker wall and chopper system; it also includes vacuum enclosures and alignment options.

13.6.5.1.1 Beam Extraction System

13.6.5.1.2 Beam Delivery System

13.6.5.1.4 Beam Geometry Conditioning:
- 13.6.5.1.4.5 Beam Shaping Slit System
- 13.6.5.1.4.6 Beam Shaping Aperture System

13.6.5.1.6 Beam validation

13.6.5.1.7 Flight tube

13.6.5.1.10 Shielding Beam Transport and Conditioning (with TUM)

[3] Please note that for clarity occasionally higher-level PBS number are included, the actual deliverable is always the lowest PBS level.

3.1.3 Heavy Shutter (ESS, TUM)

The heavy shutter inside the bunker ensures that the cave can be accessed safely while ESS is operational i.e. neutrons are produced. Currently it is planned that ESS provides two generic designs, in bunker wall and in front of bunker wall; TUM may be involved in the design of the latter.

13.6.5.1.8.3 Heavy Shutter

3.1.4 T0 Chopper (ESS)

The T0 chopper provides prompt pulse suppression; it therefore cuts off fast, relativistic neutrons and gamma radiation created by the impact of protons on the target.

13.6.5.1.3.1 T0 chopper

3.1.5 Choppers

ODIN will rely on a complex chopper system to provide unprecedented wavelength resolution paired with tunable bandwidths. It includes the whole wavelength frame multiplication chopper system.

- 13.6.5.1.3 Choppers:
  - 13.6.5.1.3.2 Wavelength frame multiplication choppers
  - 13.6.5.1.3.3 Bandpass chopper
  - 13.6.5.1.3.4 Frame overlap choppers

3.1.6 Cave Interior (PSI)

The cave houses final beam defining elements in the optical cave and the actual experimental set up in the experimental cave.

- 13.6.5.1.4 Beam Geometry Conditioning:
  - 13.6.5.1.4.5 Beam Shaping Slit System
  - 13.6.5.1.4.6 Beam Shaping Aperture System
- 13.6.5.2 Sample Exposure System:
  - 13.6.5.2.1 Sample Positioning
  - 13.6.5.2.2 Ancillary Mounting
  - 13.6.5.2.3 Sample Environment (ODIN Specific)
- 13.6.5.3 Scattering Characterization System:
  - 13.6.5.3.2.1.1 Scintillator / Camera Detector System
  - 13.6.5.3.2.2 Detector Positioning System
- 13.6.5.5 Experimental Cave:
  - 13.6.5.5.2 Utilities Distribution

3.1.7 Add ons (ESS Instrument Team) Staged PBSs

The Add on WU was specifically defined to contain experimental equipment that is foreseen for staging.

Thus, all the PBS items below are not included in the basic scope but shall be included at a later time.

- 13.6.5.1.5 Beam Filtering Systems:
  - 13.6.5.1.5.3 Neutron Polarisation system
  - 13.6.5.1.5.6 Beam Grating System
  - 13.6.5.1.5.7 SEMSANS Filter System
- 13.6.5.2.4 Non Sample Environment Ancillary equipment
- 13.6.5.3.1 Analyser Systems:
  - 13.6.5.3.1.1 Polarisation Analyser system
  - 13.6.5.3.1.2 Grating Interferometer Analyser system
  - 13.6.5.3.1.3 SEMSANS Analyser system

3.1.8 Motion Control and Electric Engineering (TUM)

The Motion Control and Electric Engineering WU integrates all instrument motion axes into the Integrated Control System (ICS); this also includes control racks for all the instrument electronics.

- 13.6.5.10 Control Racks
- 13.6.5.11.0 Integration Control and Monitoring Integration
- 13.6.5.11.1 Instrument Control and Automation:
  - 13.6.5.11.1.1 Generic Motion Control Integration
  - 13.6.5.11.1.3 Vacuum Control Integration
  - 13.6.5.11.1.4 Control Racks and Electronics Integration

3.1.9 White beam detectors (PSI)

This WU will provide white beam detectors to the instrument. White beam detectors are sensitive to the whole spectrum of the transmitted beam, they must offer reliable operations, flexibility in choosing the necessary spatial resolution and FoV. Additionally, good time resolution for kinetic studies is required.

- 13.6.5.3.2.1 Neutron Detectors:
  - 13.6.5.3.2.1.1 Scintillator / Camera Detector System

3.1.10 Time of Flight detectors (ESS Instrument Team)

Time-of-flight detectors for imaging must offer the spatial and time resolutions required for imaging. Time resolution will have to correspond to the high wavelength resolution achievable with ODIN. Within this WU, the team will continuously monitor and test new developments in detector technology in order to provide a ToF detector fitting the advanced requirements for ODIN.

A Scattering Detector System is planned as a future (long term) upgrade, here also developments at other facilities will be closely followed, even though there is no now immediate need for a decision.

- 13.6.5.3.2.1 Neutron Detectors:
  - 13.6.5.3.2.1.2 Scattering Detector System (future upgrade)
  - 13.6.5.3.2.1.3 MCP Neutron Detector

3.1.11 Shielding (TUM)

The Shielding Work unit delivers the shielding necessary for the instrument; this includes the transport neutron guide and the chopper outside the bunker wall as well as the cave and the final beam stop.

- 13.6.5.1.8 Beam Cut Off:
  - 13.6.5.1.8.4 Secondary Shutter
  - 13.6.5.1.8.7 Beam Stop
- 13.6.5.1.10 Shielding Beam Transport and Conditioning (with PSI)

3.1.12 Instrument Infrastructure

The instrument Infrastructure Work unit delivers the structural function of the experimental cave, control hutch and the interfaces to the halls floor, the distribution of media such as electricity, fluids and gases and local craning.

- 13.6.5.5.5 Cave Structure
- 13.6.5.5.2 Utilities Distribution
- 13.6.5.5.3 Support Infrastructure
- 13.6.5.6.1 Support Infrastructure
- 13.6.5.6.2 Hutch Building (Structure)
- 13.6.5.6.3 Control Terminal

3.1.13 Vacuum

See 3.2.3 below.

3.1.14 PSS

See 3.2.2 below.

3.2 Excluded

Apart from being part of the ODIN instrument team, the ESS will contribute fundamental components to each instrument assuring regulatory and safety compliance [3]. Components with relevance to ODIN are listed below for completeness.

3.2.1 Beam extraction system

- 13.6.5.1.1.1 Monolith insert:
  - 13.6.5.1.1.1.2 Monolith insert structure
  - 13.6.5.1.1.1.3 Insert alignment mechanism
  - 13.6.5.1.1.1.4 Streaming shielding
- 13.6.5.1.1.2 Monolith window

3.2.2 Personnel Safety System (PSS)

- 13.6.5.1.8.1 Personnel Safety System
- 13.6.5.5.1 Personnel Safety System

3.2.3 Vacuum System

13.6.5.1.9 Vacuum System
13.6.5.11.1.3 Vacuum Control Integration
13.6.5.10.2.5 Vacuum Control Rack
13.6.5.10.3.5 Vacuum Control Rack
13.6.5.10.4.5 Vacuum Control Rack

3.2.4 Shielding calculations

13.6.5.1.10.1.1 Shielding calculations (inside bunker)
13.6.5.1.10.2.1 Shielding calculations (outside bunker)
13.6.5.1.10.3.1 Shielding calculations (heavy collimation)
13.6.5.5.4.1 Shielding calculations (Cave)

3.2.5 Integrated Control and Monitoring

13.6.5.11.1 Instrument control integration (ICS)
13.6.5.11.2 Personnel safety system integration
13.6.5.11.3 DMSC integration

3.2.6 Supporting laboratories and sample environment

13.6.5.5.7 Sample Environment control box
13.6.5.7.4 Lab equipment storage

3.2.7 Conventional Facilities

Civil construction not mentioned above is part of the conventional facilities work project.

3.3 Deliverables

Chapter 3.1 above, Instrument Work Units, lists the relevant deliverables for each Work Unit. A more detailed overview is given by the colour coded PBS in the supporting documents.

4. PROJECT SCHEDULE

4.1 Time Schedule

The Work Project schedule for all instruments follows [4] Process for Neutron Instrument Design and Construction (ESS-0051706) and is divided into four major phases:

Phase 1	Preliminary Design
Phase 2	Detailed Design
Phase 3	Manufacturing and Procurement
Phase 4	Installation and Integration Phase

Table 2. Overview of Work Project Phases

A schematic overview is presented in Figure 1 taken from [1].

The schedule will be refined and adapted as the project progresses, but the major milestones, see section 4.2 below, serve as a basis for reporting. As a more detailed design of the instrument progresses, the project schedule will solidify.

4.2 Milestone Plan

Milestones are divided into external milestones – that are outside the control of the instrument team but yet have a major impact – and progress (internal) milestones that lie within the teams control and that are used to track progress of the Instrument. External milestones are presented in Table 3, while internal milestones are shown in Table 4.

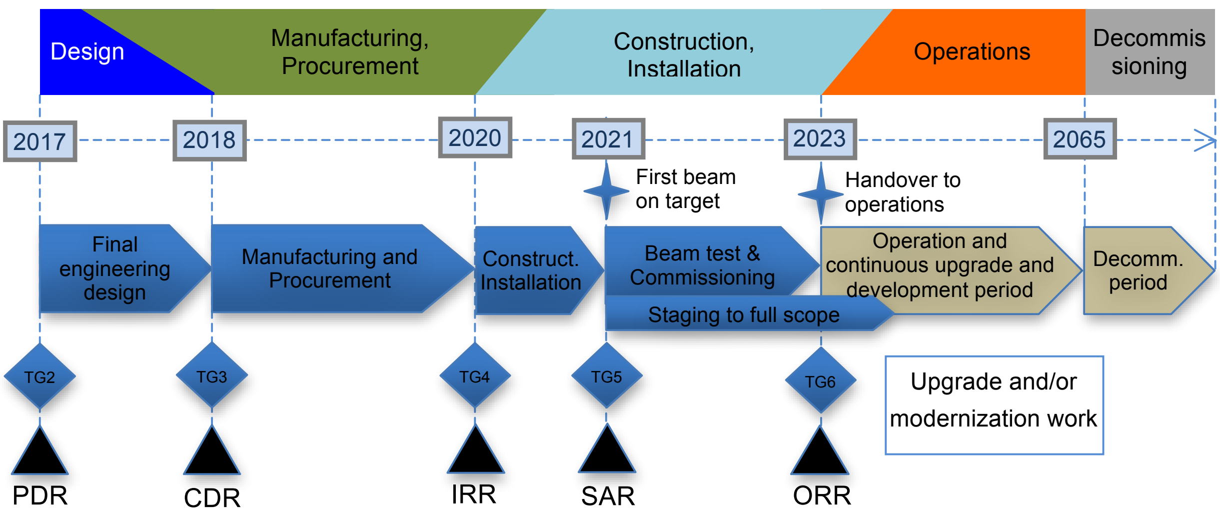

Figure 1. ODIN schematic schedule.

EXTERNAL MILESTONES	
Milestone	**Projected date**
Access to Monolith	FEB - 2019
Access to Bunker (south)	AUG - 2019
Early Access to D01 (south)	MAR - 2020
Full Access to D01 (south)	JUL - 2020
First Proton on Target, 570MeV (ACCS)	OCT - 2020

Table 3. External Milestones, Overview.

PROGRESS MILESTONES	
Milestone	**Projected date**
TG 2 decision, Detailed Design (Phase 2)	MAR - 2017
Readiness for beam extraction system Procurement	ASAP (4/2017)
Readiness for Chopper Procurement	ASAP (4/2017)
Shielding Design completed	DEC- 2017
TG3 Manufacturing & Procurement (Phase 3)	FEB - 2018
Readiness for Shielding Procurement	FEB - 2018
Readiness for Experimental Cave Procurement	MAR - 2018
Readiness for Control Hutch Procurement	JUL - 2018
Beam extraction system ready to install	OCT - 2018
Neutron (Main) Guide ready to install	OCT - 2019
Chopper system ready to install (housings)	APR - 2019
Guide Shielding ready to install	OCT - 2019
Experimental Cave ready to install	FEB - 2020
Control hutch ready to install	FEB - 2020
TG4 Installation & Integration (Phase 4)	FEB - 2020
Experimental Cave ready to accept components	SEP - 2021
Control hutch ready to accept components	JUL - 2021
Beam extraction system installed	MAR - 2019
Neutron Optics installed	SEP - 2020
Choppers inside the bunker installed	MAR - 2020
Chopper outside the bunker installed	AUG - 2020
Guide shielding outside bunker installed	DEC - 2020
Detector installed	APR - 2021
Cave Equipment and Support installed	MAR - 2021
Components integrated into EPICS	APR - 2021
ODIN ready for cold commissioning	APR - 2021
Hot Commissioning	OCT - 2021

Table 4. Internal (Progressive) Milestones.

5. PROJECT BUDGET

5.1 Project Budget

The budget discussed and finalized during the scope setting meeting is shown in Table 5 below. Individual Work Units are presented in rows except for Management and Integration shown in the third column. More detailed information can be found in the supporting material.

	Cost Overview		Detailed Cost					
WU	**Non-Labor**	**Labor**	**01** Manage-ment	**02** Design	**03** Procurem. Labor	**04** Installation	**05** Cold Com-missioning	**Total**
00 Phase 1	0 €	554,000 €	-	-	-	-	-	**554,000 €**
02 Neutron Transport	1,600,000 €	342,000 €	75,300 €	102,000 €	44,000 €	49,400 €	70,800 €	**341,500 €**
03 Heavy Shutter	175,000 €	173,000 €	40,700 €	58,400 €	15,900 €	33,300 €	24,600 €	**173,000 €**
04 T0 Chopper	170,000 €	115,000 €	25,900 €	40,100 €	14,000 €	15,100 €	19,400 €	**114,500 €**
05 Choppers	1,696,000 €	370,000 €	82,700 €	98,500 €	42,100 €	69,700 €	77,000 €	**370,000 €**
06 Cave Interior	730,000 €	428,000 €	96,200 €	81,300 €	73,100 €	81,800 €	95,400 €	**427,800 €**
07 Add ons	0 €	0 €	-	-	-	-	-	**-**
08 Motion Control and EE	102,000 €	266,000 €	55,500 €	59,600 €	41,200 €	62,600 €	47,200 €	**266,100 €**
09 White beam detectors	225,000 €	161,000 €	38,200 €	44,700 €	22,500 €	33,300 €	22,600 €	**161,300 €**
10 ToF Detectors	250,000 €	96,000 €	19,800 €	28,700 €	16,800 €	16,100 €	14,300 €	**95,700 €**
11 Shielding	2,265,000 €	360,000 €	98,700 €	127,200 €	40,200 €	71,700 €	22,600 €	**360,400 €**
12 Instrument Infrastructure	99,000 €	179,000 €	39,500 €	48,100 €	27,100 €	38,400 €	25,700 €	**178,700 €**
13 Vacuum	0 €	0 €	-	-	-	-	-	**-**
14 PSS	95,000 €	54,000 €	14,800 €	8,000 €	11,200 €	11,100 €	9,200 €	**54,300 €**
Travel	92,000 €	0 €	-	-	-	-	-	**-**
Contingency	750,000 €	254,000 €	58,700 €	69,700 €	34,900 €	48,200 €	42,900 €	**254,400 €**
Totals	**8,249,000 €**	**3,352,000 €**	**646,000 €**	**766,300 €**	**383,000 €**	**530,700 €**	**471,700 €**	**554,000 € + 2,797,700 €**
	11,601,000 €							

Table 5. Combined, total Budget by Work Units.

6. PROJECT RISK MANAGEMENT

The risks are accessed according to ESS risk management practice. Here only risks that lie within the instrument team's control are presented. Risks are divided into technical, cost and schedule risks. Their probability and consequence is rated on a scale of 1-5 (where 1 denotes low probability or minor consequence, respectively). The risk level is then calculated by multiplying probability by estimated consequences.

The high, medium and low- risk levels were defined following ESS procedure, see Table 6.

Probability \ Consequence	1	2	3	4	5
5				Hi	gh
4					
3		Med	ium		
2	Low				
1					

Table 6. Risk assessment levels.

6.1 Risk List

Technical				
Risk	**Probability**	**Consequence**	**Risk level**	**Mitigation**
Bunker Design interferes with Chopper positions	5	4	20	Communication with Bunker group, re-design of pillar layout
Bi-spectral extraction system does not perform as expected	2	4	8	Accept lower performance
Shielding does not meet requirements	2	4	8	Add additional shielding
High background in cave	1	3	3	Add shielding along beampath
Cost				
Risk	**Probability**	**Consequence**	**Risk level**	**Mitigation**
Underestimated price and design of shielding	2	3	6	Use of contingency
Experimental Cave and Control hutch cost increase	1	2	2	Use of contingency
Increased cost exceeds available contingency	2	2	4	Negotiate Scope and Budget with ESS
Schedule				
Risk	**Probability**	**Consequence**	**Risk level**	**Mitigation**
Delays in procurement	2	2	4	Early procurement
Delays in deliveries	2	2	4	Early procurement
Delay in signing contracts	2	4	8	Early start of negotiations
Delay in installation of in-bunker components	2	5	10	Installation planning with ESS and neighboring instruments
Delay in access to instrument halls	2	4	8	Early delivery of components, careful installation planning
Key personnel left the project	2	4	8	Find new personnel
Delay of integration of special purpose motion into EPICS	2	3	6	Early start of integration

Table 7. Risk Summary

6.2 Risk Monitoring and Control

ESS risk management procedures will be followed. The risk register will be maintained and updated in regularly. The updated risk register will also be available to the Instrument Construction Sub-Project and the NSS Project for higher-level risk monitoring. If a risk is realised it will be reported to the Instrument Construction Sub-Project even if it has no direct consequence at that level.

7. GLOSSARY

Term	Definition
ASAP	As soon as possible
BP	Bandpass (-width) Chopper
CDR	Critical Design Review
ConOps	Concepts of Operations
FOC	Frame Overlap Chopper
IRR	Installation Readiness Review
ODIN	Optical and Diffraction Imaging with Neutrons
ORR	Operational Readiness Review
PDR	Preliminary Design Review
PPSC	Prompt Pulse Suppression Chopper
PSS	Personnel Safety System
SAR	Safety System Acceptance Review
T0	Pulse Shaping Chopper (t=0 chopper)
TG	Toll gate
WFMC	Wavelength Frame Multiplication Chopper

8. REFERENCES

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DOCUMENT REVISION HISTORY

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0	First Draft	Markus Strobl, Peter Sangberg	2016-05-16
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