



BSI Standards Publication

Programming languages — Guidance to avoiding vulnerabilities in programming languages

Part 1: Language-independent guidance

National foreword

This Published Document is the UK implementation of ISO/IEC TR 24772-1:2019. It supersedes PD ISO/IEC TR 24772:2013, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee IST/5, Programming languages, their environments and system software interfaces.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2019
Published by BSI Standards Limited 2019

ISBN 978 0 539 02543 9

ICS 35.060

Compliance with a British Standard cannot confer immunity from legal obligations.

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 December 2019.

Amendments/corrigenda issued since publication

Date	Text affected
------	---------------

TECHNICAL
REPORT

ISO/IEC TR
24772-1

First edition
2019-12

**Programming languages — Guidance
to avoiding vulnerabilities in
programming languages**

**Part 1:
Language-independent guidance**

*Langages de programmation — Conduite pour éviter les
vulnérabilités dans les langages de programmation —*

Partie 1: Conduite indépendante du langage



Reference number
ISO/IEC TR 24772-1:2019(E)

© ISO/IEC 2019



COPYRIGHT PROTECTED DOCUMENT

© ISO/IEC 2019

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword	xv
Introduction	xvi
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
3.1 Terms related to communication.....	1
3.2 Terms related to execution model.....	2
3.3 Properties.....	4
3.4 Safety.....	4
3.5 Vulnerabilities.....	4
4 Applying this document	5
5 Vulnerability issues and general avoidance mechanisms	7
5.1 Predictable execution.....	7
5.2 Sources of unpredictability in language specification.....	8
5.2.1 Incomplete or evolving specification.....	8
5.2.2 Undefined behaviour.....	8
5.2.3 Unspecified behaviour.....	8
5.2.4 Implementation-defined behaviour.....	8
5.2.5 Difficult features.....	8
5.2.6 Inadequate language support.....	8
5.3 Sources of unpredictability in language usage.....	9
5.3.1 Porting and interoperation.....	9
5.3.2 Compiler selection and usage.....	9
5.4 Top avoidance mechanisms.....	9
6 Programming language vulnerabilities	11
6.1 General.....	11
6.2 Type system [IHN].....	11
6.2.1 Description of application vulnerability.....	11
6.2.2 Cross reference.....	11
6.2.3 Mechanism of failure.....	11
6.2.4 Applicable language characteristics.....	13
6.2.5 Avoiding the vulnerability or mitigating its effects.....	13
6.2.6 Implications for language design and evolution.....	14
6.3 Bit representations [STR].....	14
6.3.1 Description of application vulnerability.....	14
6.3.2 Cross reference.....	14
6.3.3 Mechanism of failure.....	14
6.3.4 Applicable language characteristics.....	15
6.3.5 Avoiding the vulnerability or mitigating its effects.....	15
6.3.6 Implications for language design and evolution.....	15
6.4 Floating-point arithmetic [PLF].....	15
6.4.1 Description of application vulnerability.....	15
6.4.2 Cross reference.....	16
6.4.3 Mechanism of failure.....	16
6.4.4 Applicable language characteristics.....	17
6.4.5 Avoiding the vulnerability or mitigating its effects.....	17
6.4.6 Implications for language design and evolution.....	17
6.5 Enumerator issues [CCB].....	18
6.5.1 Description of application vulnerability.....	18
6.5.2 Cross reference.....	18
6.5.3 Mechanism of failure.....	18
6.5.4 Applicable language characteristics.....	19

6.5.5	Avoiding the vulnerability or mitigating its effects	19
6.5.6	Implications for language design and evolution	19
6.6	Conversion errors [FLC]	19
6.6.1	Description of application vulnerability	19
6.6.2	Cross reference	20
6.6.3	Mechanism of failure	20
6.6.4	Applicable language characteristics	20
6.6.5	Avoiding the vulnerability or mitigating its effects	21
6.6.6	Implications for language design and evolution	21
6.7	String termination [CJM]	21
6.7.1	Description of application vulnerability	21
6.7.2	Cross reference	21
6.7.3	Mechanism of failure	22
6.7.4	Applicable language characteristics	22
6.7.5	Avoiding the vulnerability or mitigating its effects	22
6.7.6	Implications for language design and evolution	22
6.8	Buffer boundary violation (buffer overflow) [HCB]	22
6.8.1	Description of application vulnerability	22
6.8.2	Cross reference	22
6.8.3	Mechanism of failure	23
6.8.4	Applicable language characteristics	23
6.8.5	Avoiding the vulnerability or mitigating its effects	24
6.8.6	Implications for language design and evolution	24
6.9	Unchecked array indexing [XYZ]	24
6.9.1	Description of application vulnerability	24
6.9.2	Cross reference	25
6.9.3	Mechanism of failure	25
6.9.4	Applicable language characteristics	25
6.9.5	Avoiding the vulnerability or mitigating its effects	26
6.9.6	Implications for language designers	26
6.10	Unchecked array copying [XYW]	26
6.10.1	Description of application vulnerability	26
6.10.2	Cross reference	26
6.10.3	Mechanism of failure	26
6.10.4	Applicable language characteristics	27
6.10.5	Avoiding the vulnerability or mitigating its effects	27
6.10.6	Implications for language design and evolution	27
6.11	Pointer type conversions [HFC]	27
6.11.1	Description of application vulnerability	27
6.11.2	Cross reference	28
6.11.3	Mechanism of failure	28
6.11.4	Applicable language characteristics	28
6.11.5	Avoiding the vulnerability or mitigating its effects	28
6.11.6	Implications for language design and evolution	29
6.12	Pointer arithmetic [RVG]	29
6.12.1	Description of application vulnerability	29
6.12.2	Cross reference	29
6.12.3	Mechanism of failure	29
6.12.4	Applicable language characteristics	29
6.12.5	Avoiding the vulnerability or mitigating its effects	29
6.12.6	Implications for language design and evolution	29
6.13	Null pointer dereference [XYH]	29
6.13.1	Description of application vulnerability	29
6.13.2	Cross reference	30
6.13.3	Mechanism of failure	30
6.13.4	Applicable language characteristics	30
6.13.5	Avoiding the vulnerability or mitigating its effects	30
6.13.6	Implications for language design and evolution	30

6.14	Dangling reference to heap [XYK]	30
6.14.1	Description of application vulnerability	30
6.14.2	Cross reference	31
6.14.3	Mechanism of failure	31
6.14.4	Applicable language characteristics	31
6.14.5	Avoiding the vulnerability or mitigating its effects	32
6.14.6	Implications for language design and evolution	32
6.15	Arithmetic wrap-around error [FIF]	32
6.15.1	Description of application vulnerability	32
6.15.2	Cross reference	32
6.15.3	Mechanism of failure	33
6.15.4	Applicable language characteristics	33
6.15.5	Avoiding the vulnerability or mitigating its effects	33
6.15.6	Implications for language design and evolution	33
6.16	Using shift operations for multiplication and division [PIK]	34
6.16.1	Description of application vulnerability	34
6.16.2	Cross reference	34
6.16.3	Mechanism of failure	34
6.16.4	Applicable language characteristics	34
6.16.5	Avoiding the vulnerability or mitigating its effects	34
6.16.6	Implications for language design and evolution	34
6.17	Choice of clear names [NAI]	35
6.17.1	Description of application vulnerability	35
6.17.2	Cross reference	35
6.17.3	Mechanism of Failure	35
6.17.4	Applicable language characteristics	36
6.17.5	Avoiding the vulnerability or mitigating its effects	36
6.17.6	Implications for language design and evolution	36
6.18	Dead store [WXQ]	36
6.18.1	Description of application vulnerability	36
6.18.2	Cross reference	36
6.18.3	Mechanism of failure	37
6.18.4	Applicable language characteristics	37
6.18.5	Avoiding the vulnerability or mitigating its effects	37
6.18.6	Implications for language design and evolution	37
6.19	Unused variable [Y2S]	38
6.19.1	Description of application vulnerability	38
6.19.2	Cross reference	38
6.19.3	Mechanism of failure	38
6.19.4	Applicable language characteristics	38
6.19.5	Avoiding the vulnerability or mitigating its effects	38
6.19.6	Implications for language design and evolution	38
6.20	Identifier name reuse [YOW]	38
6.20.1	Description of application vulnerability	38
6.20.2	Cross reference	39
6.20.3	Mechanism of failure	39
6.20.4	Applicable language characteristics	40
6.20.5	Avoiding the vulnerability or mitigating its effects	40
6.20.6	Implications for language design and evolution	40
6.21	Namespace issues [BJL]	40
6.21.1	Description of application vulnerability	40
6.21.2	Cross-references	41
6.21.3	Mechanism of failure	41
6.21.4	Applicable language characteristics	41
6.21.5	Avoiding the vulnerability or mitigating its effects	41
6.21.6	Implications for language design and evolution	42
6.22	Initialization of variables [LAV]	42
6.22.1	Description of application vulnerability	42

6.22.2	Cross reference.....	42
6.22.3	Mechanism of failure.....	42
6.22.4	Applicable language characteristics.....	43
6.22.5	Avoiding the vulnerability or mitigating its effects.....	43
6.22.6	Implications for language design and evolution.....	44
6.23	Operator precedence and associativity [JCW].....	44
6.23.1	Description of application vulnerability.....	44
6.23.2	Cross reference.....	44
6.23.3	Mechanism of failure.....	44
6.23.4	Applicable language characteristics.....	45
6.23.5	Avoiding the vulnerability or mitigating its effects.....	45
6.23.6	Implications for language design and evolution.....	45
6.24	Side-effects and order of evaluation of operands [SAM].....	45
6.24.1	Description of application vulnerability.....	45
6.24.2	Cross reference.....	45
6.24.3	Mechanism of failure.....	46
6.24.4	Applicable language characteristics.....	46
6.24.5	Avoiding the vulnerability or mitigating its effects.....	46
6.24.6	Implications for language design and evolution.....	46
6.25	Likely incorrect expression [KOA].....	47
6.25.1	Description of application vulnerability.....	47
6.25.2	Cross reference.....	47
6.25.3	Mechanism of failure.....	47
6.25.4	Applicable language characteristics.....	48
6.25.5	Avoiding the vulnerability or mitigating its effects.....	48
6.25.6	Implications for language design and evolution.....	48
6.26	Dead and deactivated code [XYQ].....	48
6.26.1	Description of application vulnerability.....	48
6.26.2	Cross reference.....	48
6.26.3	Mechanism of failure.....	49
6.26.4	Applicable language characteristics.....	50
6.26.5	Avoiding the vulnerability or mitigating its effects.....	50
6.26.6	Implications for language design and evolution.....	50
6.27	Switch statements and static analysis [CLL].....	50
6.27.1	Description of application vulnerability.....	50
6.27.2	Cross reference.....	50
6.27.3	Mechanism of failure.....	51
6.27.4	Applicable language characteristics.....	51
6.27.5	Avoiding the vulnerability or mitigating its effects.....	51
6.27.6	Implications for language design and evolution.....	51
6.28	Demarcation of control flow [EOJ].....	52
6.28.1	Description of application vulnerability.....	52
6.28.2	Cross reference.....	52
6.28.3	Mechanism of failure.....	52
6.28.4	Applicable language characteristics.....	52
6.28.5	Avoiding the vulnerability or mitigating its effects.....	52
6.28.6	Implications for language design and evolution.....	53
6.29	Loop control variables [TEX].....	53
6.29.1	Description of application vulnerability.....	53
6.29.2	Cross reference.....	53
6.29.3	Mechanism of failure.....	53
6.29.4	Applicable language characteristics.....	53
6.29.5	Avoiding the vulnerability or mitigating its effects.....	53
6.29.6	Implications for language design and evolution.....	54
6.30	Off-by-one error [XZH].....	54
6.30.1	Description of application vulnerability.....	54
6.30.2	Cross reference.....	54
6.30.3	Mechanism of failure.....	54

6.30.4	Applicable language characteristics.....	55
6.30.5	Avoiding the vulnerability or mitigating its effects.....	55
6.30.6	Implications for language design and evolution.....	55
6.31	Unstructured programming [EWD].....	55
6.31.1	Description of application vulnerability.....	55
6.31.2	Cross reference.....	55
6.31.3	Mechanism of failure.....	56
6.31.4	Applicable language characteristics.....	56
6.31.5	Avoiding the vulnerability or mitigating its effects.....	56
6.31.6	Implications for language design and evolution.....	56
6.32	Passing parameters and return values [CSJ].....	56
6.32.1	Description of application vulnerability.....	56
6.32.2	Cross reference.....	57
6.32.3	Mechanism of failure.....	57
6.32.4	Applicable language characteristics.....	58
6.32.5	Avoiding the vulnerability or mitigating its effects.....	58
6.32.6	Implications for language design and evolution.....	58
6.33	Dangling references to stack frames [DCM].....	58
6.33.1	Description of application vulnerability.....	58
6.33.2	Cross reference.....	59
6.33.3	Mechanism of failure.....	59
6.33.4	Applicable language characteristics.....	60
6.33.5	Avoiding the vulnerability or mitigating its effects.....	60
6.33.6	Implications for language design and evolution.....	60
6.34	Subprogram signature mismatch [OTR].....	60
6.34.1	Description of application vulnerability.....	60
6.34.2	Cross reference.....	60
6.34.3	Mechanism of failure.....	61
6.34.4	Applicable language characteristics.....	61
6.34.5	Avoiding the vulnerability or mitigating its effects.....	61
6.34.6	Implications for language design and evolution.....	61
6.35	Recursion [GDL].....	62
6.35.1	Description of application vulnerability.....	62
6.35.2	Cross reference.....	62
6.35.3	Mechanism of failure.....	62
6.35.4	Applicable language characteristics.....	62
6.35.5	Avoiding the vulnerability or mitigating its effects.....	62
6.35.6	Implications for language design and evolution.....	63
6.36	Ignored error status and unhandled exceptions [OYB].....	63
6.36.1	Description of application vulnerability.....	63
6.36.2	Cross reference.....	63
6.36.3	Mechanism of failure.....	63
6.36.4	Applicable language characteristics.....	64
6.36.5	Avoiding the vulnerability or mitigating its effects.....	64
6.36.6	Implications for language design and evolution.....	65
6.37	Type-breaking reinterpretation of data [AMV].....	65
6.37.1	Description of application vulnerability.....	65
6.37.2	Cross reference.....	65
6.37.3	Mechanism of failure.....	65
6.37.4	Applicable language characteristics.....	66
6.37.5	Avoiding the vulnerability or mitigating its effects.....	66
6.37.6	Implications for language design and evolution.....	66
6.38	Deep vs. shallow copying [YAN].....	67
6.38.1	Description of application vulnerability.....	67
6.38.2	Cross reference.....	67
6.38.3	Mechanism of failure.....	67
6.38.4	Applicable language characteristics.....	67
6.38.5	Avoiding the vulnerability or mitigating its effects.....	67

6.38.6	Implications for language design and evolution	68
6.39	Memory leaks and heap fragmentation [XYL]	68
6.39.1	Description of application vulnerability	68
6.39.2	Cross reference	68
6.39.3	Mechanism of failure	68
6.39.4	Applicable language characteristics	68
6.39.5	Avoiding the vulnerability or mitigating its effects	69
6.39.6	Implications for language design and evolution	69
6.40	Templates and generics [SYM]	69
6.40.1	Description of application vulnerability	69
6.40.2	Cross reference	70
6.40.3	Mechanism of failure	70
6.40.4	Applicable language characteristics	70
6.40.5	Avoiding the vulnerability or mitigating its effects	71
6.40.6	Implications for language design and evolution	71
6.41	Inheritance [RIP]	71
6.41.1	Description of application vulnerability	71
6.41.2	Cross reference	71
6.41.3	Mechanism of failure	72
6.41.4	Applicable language characteristics	72
6.41.5	Avoiding the vulnerability or mitigating its effects	72
6.41.6	Implications for language design and evolution	73
6.42	Violations of the Liskov substitution principle or the contract model [BLP]	73
6.42.1	Description of application vulnerability	73
6.42.2	Cross reference	74
6.42.3	Mechanism of failure	74
6.42.4	Applicable language characteristics	74
6.42.5	Avoiding the vulnerability or mitigating its effects	74
6.42.6	Implications for language design and evolution	74
6.43	Redispatching [PPH]	74
6.43.1	Description of application vulnerability	74
6.43.2	Cross reference	75
6.43.3	Mechanism of failure	75
6.43.4	Applicable language characteristics	75
6.43.5	Avoiding the vulnerability or mitigating its effects	75
6.43.6	Implications for language design and evolution	75
6.44	Polymorphic variables [BNS]	75
6.44.1	Description of application vulnerability	75
6.44.2	Cross reference	76
6.44.3	Mechanism of failure	76
6.44.4	Applicable language characteristics	77
6.44.5	Avoiding the vulnerability or mitigating its effects	77
6.44.6	Implications for language design and evolution	77
6.45	Extrinsic ininsics [LRM]	77
6.45.1	Description of application vulnerability	77
6.45.2	Cross reference	77
6.45.3	Mechanism of failure	77
6.45.4	Applicable language characteristics	78
6.45.5	Avoiding the vulnerability or mitigating its effects	78
6.45.6	Implications for language design and evolution	78
6.46	Argument passing to library functions [TRJ]	78
6.46.1	Description of application vulnerability	78
6.46.2	Cross reference	78
6.46.3	Mechanism of failure	78
6.46.4	Applicable language characteristics	79
6.46.5	Avoiding the vulnerability or mitigating its effects	79
6.46.6	Implications for language design and evolution	79
6.47	Inter-language calling [DJS]	79

6.47.1	Description of application vulnerability.....	79
6.47.2	Cross reference.....	79
6.47.3	Mechanism of failure.....	79
6.47.4	Applicable language characteristics.....	80
6.47.5	Avoiding the vulnerability or mitigating its effects.....	80
6.47.6	Implications for language design and evolution.....	81
6.48	Dynamically-linked code and self-modifying code [NYY].....	81
6.48.1	Description of application vulnerability.....	81
6.48.2	Cross reference.....	81
6.48.3	Mechanism of failure.....	81
6.48.4	Applicable language characteristics.....	81
6.48.5	Avoiding the vulnerability or mitigating its effects.....	82
6.48.6	Implications for language design and evolution.....	82
6.49	Library signature [NSQ].....	82
6.49.1	Description of application vulnerability.....	82
6.49.2	Cross reference.....	82
6.49.3	Mechanism of failure.....	82
6.49.4	Applicable language characteristics.....	83
6.49.5	Avoiding the vulnerability or mitigating its effects.....	83
6.49.6	Implications for language design and evolution.....	83
6.50	Unanticipated exceptions from library routines [HJW].....	83
6.50.1	Description of application vulnerability.....	83
6.50.2	Cross reference.....	83
6.50.3	Mechanism of failure.....	83
6.50.4	Applicable language characteristics.....	84
6.50.5	Avoiding the vulnerability or mitigating its effects.....	84
6.50.6	Implications for language design and evolution.....	84
6.51	Pre-processor directives [NMP].....	84
6.51.1	Description of application vulnerability.....	84
6.51.2	Cross reference.....	84
6.51.3	Mechanism of failure.....	85
6.51.4	Applicable language characteristics.....	85
6.51.5	Avoiding the vulnerability or mitigating its effects.....	85
6.51.6	Implications for language design and evolution.....	85
6.52	Suppression of language-defined run-time checking [MXB].....	86
6.52.1	Description of application vulnerability.....	86
6.52.2	Cross reference.....	86
6.52.3	Mechanism of Failure.....	86
6.52.4	Applicable language characteristics.....	86
6.52.5	Avoiding the vulnerability.....	86
6.52.6	Implications for language design and evolution.....	86
6.53	Provision of inherently unsafe operations [SKL].....	87
6.53.1	Description of application vulnerability.....	87
6.53.2	Cross reference.....	87
6.53.3	Mechanism of Failure.....	87
6.53.4	Applicable language characteristics.....	87
6.53.5	Avoiding the vulnerability.....	87
6.53.6	Implications for language design and evolution.....	88
6.54	Obscure language features [BRS].....	88
6.54.1	Description of application vulnerability.....	88
6.54.2	Cross reference.....	88
6.54.3	Mechanism of failure.....	88
6.54.4	Applicable language characteristics.....	88
6.54.5	Avoiding the vulnerability or mitigating its effects.....	88
6.54.6	Implications for language design and evolution.....	89
6.55	Unspecified behaviour [BQF].....	89
6.55.1	Description of application vulnerability.....	89
6.55.2	Cross reference.....	89

6.55.3	Mechanism of failure	89
6.55.4	Applicable language characteristics	90
6.55.5	Avoiding the vulnerability or mitigating its effects	90
6.55.6	Implications for language design and evolution	90
6.56	Undefined behaviour [EWF]	90
6.56.1	Description of application vulnerability	90
6.56.2	Cross reference	91
6.56.3	Mechanism of failure	91
6.56.4	Applicable language characteristics	91
6.56.5	Avoiding the vulnerability or mitigating its effects	91
6.56.6	Implications for language design and evolution	92
6.57	Implementation-defined behaviour [FAB]	92
6.57.1	Description of application vulnerability	92
6.57.2	Cross reference	92
6.57.3	Mechanism of failure	92
6.57.4	Applicable language characteristics	93
6.57.5	Avoiding the vulnerability or mitigating its effects	93
6.57.6	Implications for language design and evolution	93
6.58	Deprecated language features [MEM]	93
6.58.1	Description of application vulnerability	93
6.58.2	Cross reference	94
6.58.3	Mechanism of failure	94
6.58.4	Applicable language characteristics	94
6.58.5	Avoiding the vulnerability or mitigating its effects	94
6.58.6	Implications for language design and evolution	95
6.59	Concurrency — Activation [CGA]	95
6.59.1	Description of application vulnerability	95
6.59.2	Cross-references	95
6.59.3	Mechanism of Failure	95
6.59.4	Applicable language characteristics	96
6.59.5	Avoiding the vulnerability or mitigating its effects	96
6.59.6	Implications for language design and evolution	96
6.60	Concurrency — Directed termination [CGT]	96
6.60.1	Description of application vulnerability	96
6.60.2	Cross-references	97
6.60.3	Mechanism of failure	97
6.60.4	Applicable language characteristics	97
6.60.5	Avoiding the vulnerability or mitigating its effect	97
6.60.6	Implications for language design and evolution	98
6.61	Concurrent data access [CGX]	98
6.61.1	Description of application vulnerability	98
6.61.2	Cross-references	98
6.61.3	Mechanism of failure	98
6.61.4	Applicable language characteristics	98
6.61.5	Avoiding the vulnerability or mitigating its effect	99
6.61.6	Implications for language design and evolution	99
6.62	Concurrency — Premature termination [CGS]	99
6.62.1	Description of application vulnerability	99
6.62.2	Cross-references	99
6.62.3	Mechanism of failure	100
6.62.4	Applicable language characteristics	100
6.62.5	Avoiding the vulnerability or mitigating its effect	100
6.62.6	Implications for language design and evolution	101
6.63	Lock protocol errors [CGM]	101
6.63.1	Description of application vulnerability	101
6.63.2	Cross-references	101
6.63.3	Mechanism of failure	102
6.63.4	Applicable language characteristics	102

6.63.5	Avoiding the vulnerability or mitigating its effect	102
6.63.6	Implications for language design and evolution	103
6.64	Reliance on external format strings [SHL]	103
6.64.1	Description of application vulnerability	103
6.64.2	Cross reference	103
6.64.3	Mechanism of failure	103
6.64.4	Applicable language characteristics	104
6.64.5	Avoiding the vulnerability or mitigating its effects	104
6.64.6	Implications for language design and evolution	104
7	Application vulnerabilities	105
7.1	General	105
7.2	Unrestricted file upload [CBF]	105
7.2.1	Description of application vulnerability	105
7.2.2	Cross reference	105
7.2.3	Mechanism of failure	105
7.2.4	Avoiding the vulnerability or mitigating its effects	105
7.3	Download of code without integrity check [DLB]	106
7.3.1	Description of application vulnerability	106
7.3.2	Cross reference	106
7.3.3	Mechanism of failure	106
7.3.4	Avoiding the vulnerability or mitigating its effects	106
7.4	Executing or loading untrusted code [XYS]	107
7.4.1	Description of application vulnerability	107
7.4.2	Cross reference	107
7.4.3	Mechanism of failure	107
7.4.4	Avoiding the vulnerability or mitigating its effects	107
7.5	Inclusion of functionality from untrusted control sphere [DHU]	108
7.5.1	Description of application vulnerability	108
7.5.2	Cross reference	108
7.5.3	Mechanism of failure	108
7.5.4	Avoiding the vulnerability or mitigating its effects	108
7.6	Use of unchecked data from an uncontrolled or tainted source [EFS]	108
7.6.1	Description of application vulnerability	108
7.6.2	Cross reference	109
7.6.3	Mechanism of failure	109
7.6.4	Avoiding the vulnerability or mitigating its effects	109
7.7	Cross-site scripting [XYT]	109
7.7.1	Description of application vulnerability	109
7.7.2	Cross reference	109
7.7.3	Mechanism of failure	110
7.7.4	Avoiding the vulnerability or mitigating its effects	111
7.8	URL redirection to untrusted site ("open redirect") [PYQ]	112
7.8.1	Description of application vulnerability	112
7.8.2	Cross reference	112
7.8.3	Mechanism of failure	112
7.8.4	Avoiding the vulnerability or mitigating its effects	112
7.9	Injection [RST]	112
7.9.1	Description of application vulnerability	112
7.9.2	Cross reference	113
7.9.3	Mechanism of failure	114
7.9.4	Avoiding the vulnerability or mitigating its effects	115
7.10	Unquoted search path or element [XZQ]	115
7.10.1	Description of application vulnerability	115
7.10.2	Cross reference	115
7.10.3	Mechanism of failure	115
7.10.4	Avoiding the vulnerability or mitigating its effects	115
7.11	Path traversal [EWR]	116
7.11.1	Description of application vulnerability	116

7.11.2	Cross reference	116
7.11.3	Mechanism of failure	116
7.11.4	Avoiding the vulnerability or mitigating its effects	118
7.12	Resource names [HTS]	118
7.12.1	Description of application vulnerability	118
7.12.2	Cross reference	119
7.12.3	Mechanism of Failure	119
7.12.4	Avoiding the vulnerability or mitigating its effects	119
7.13	Resource exhaustion [XZP]	119
7.13.1	Description of application vulnerability	119
7.13.2	Cross reference	119
7.13.3	Mechanism of failure	119
7.13.4	Avoiding the vulnerability or mitigating its effects	120
7.14	Authentication logic error [XZO]	120
7.14.1	Description of application vulnerability	120
7.14.2	Cross reference	120
7.14.3	Mechanism of failure	121
7.14.4	Avoiding the vulnerability or mitigating its effects	122
7.15	Improper restriction of excessive authentication attempts [WPL]	122
7.15.1	Description of application vulnerability	122
7.15.2	Cross reference	122
7.15.3	Mechanism of failure	122
7.15.4	Avoiding the vulnerability or mitigating its effects	122
7.16	Hard-coded credentials [XYP]	123
7.16.1	Description of application vulnerability	123
7.16.2	Cross reference	123
7.16.3	Mechanism of failure	123
7.16.4	Avoiding the vulnerability or mitigating its effects	123
7.17	Insufficiently protected credentials [XYM]	124
7.17.1	Description of application vulnerability	124
7.17.2	Cross reference	124
7.17.3	Mechanism of failure	124
7.17.4	Avoiding the vulnerability or mitigating its effects	124
7.18	Missing or inconsistent access control [XZN]	125
7.18.1	Description of application vulnerability	125
7.18.2	Cross reference	125
7.18.3	Mechanism of failure	125
7.18.4	Avoiding the vulnerability or mitigating its effects	125
7.19	Incorrect authorization [BJE]	125
7.19.1	Description of application vulnerability	125
7.19.2	Cross reference	125
7.19.3	Mechanism of failure	125
7.19.4	Avoiding the vulnerability or mitigating its effects	126
7.20	Adherence to least privilege [XYN]	126
7.20.1	Description of application vulnerability	126
7.20.2	Cross reference	126
7.20.3	Mechanism of failure	126
7.20.4	Avoiding the vulnerability or mitigating its effects	126
7.21	Privilege sandbox issues [XYO]	127
7.21.1	Description of application vulnerability	127
7.21.2	Cross reference	127
7.21.3	Mechanism of failure	127
7.21.4	Avoiding the vulnerability or mitigating its effects	128
7.22	Missing required cryptographic step [XZS]	128
7.22.1	Description of application vulnerability	128
7.22.2	Cross reference	128
7.22.3	Mechanism of failure	128
7.22.4	Avoiding the vulnerability or mitigating its effects	128

7.23	Improperly verified signature [XZR].....	129
	7.23.1 Description of application vulnerability.....	129
	7.23.2 Cross reference.....	129
	7.23.3 Mechanism of failure.....	129
	7.23.4 Avoiding the vulnerability or mitigating its effects.....	129
7.24	Use of a one-way hash without a salt [MVX].....	129
	7.24.1 Description of application vulnerability.....	129
	7.24.2 Cross reference.....	129
	7.24.3 Mechanism of failure.....	129
	7.24.4 Avoiding the vulnerability or mitigating its effects.....	130
7.25	Inadequately secure communication of shared resources [CGY].....	130
	7.25.1 Description of application vulnerability.....	130
	7.25.2 Cross-references.....	130
	7.25.3 Mechanism of failure.....	130
	7.25.4 Avoiding the vulnerability or mitigating its effect.....	131
7.26	Memory locking [XZX].....	131
	7.26.1 Description of application vulnerability.....	131
	7.26.2 Cross reference.....	131
	7.26.3 Mechanism of failure.....	132
	7.26.4 Avoiding the vulnerability or mitigating its effects.....	132
7.27	Sensitive information not cleared before use [XZK].....	132
	7.27.1 Description of application vulnerability.....	132
	7.27.2 Cross reference.....	132
	7.27.3 Mechanism of failure.....	132
	7.27.4 Avoiding the vulnerability or mitigating its effects.....	133
7.28	Time consumption measurement [CCM].....	133
	7.28.1 Description of application vulnerability.....	133
	7.28.2 Cross-references.....	133
	7.28.3 Mechanism of failure.....	133
	7.28.4 Avoiding the vulnerability or mitigating its effect.....	133
7.29	Discrepancy information leak [XZL].....	134
	7.29.1 Description of application vulnerability.....	134
	7.29.2 Cross reference.....	134
	7.29.3 Mechanism of failure.....	134
	7.29.4 Avoiding the vulnerability or mitigating its effects.....	134
7.30	Unspecified functionality [BVQ].....	135
	7.30.1 Description of application vulnerability.....	135
	7.30.2 Cross reference.....	135
	7.30.3 Mechanism of failure.....	135
	7.30.4 Avoiding the vulnerability or mitigating its effects.....	135
7.31	Fault tolerance and failure strategies [REU].....	136
	7.31.1 Description of application vulnerability.....	136
	7.31.2 Cross reference.....	136
	7.31.3 Mechanism of failure.....	137
	7.31.4 Avoiding the vulnerability or mitigating its effects.....	137
7.32	Distinguished values in data types [KLK].....	138
	7.32.1 Description of application vulnerability.....	138
	7.32.2 Cross reference.....	138
	7.32.3 Mechanism of failure.....	138
	7.32.4 Avoiding the vulnerability or mitigating its effects.....	139
7.33	Clock issues [CCI].....	139
	7.33.1 Description of application vulnerability.....	139
	7.33.2 Cross-references.....	140
	7.33.3 Mechanism of failure.....	140
	7.33.4 Avoiding the vulnerability or mitigating its effect.....	141
7.34	Time drift and jitter [CDJ].....	141
	7.34.1 Description of application vulnerability.....	141
	7.34.2 Cross-references.....	142

7.34.3	Mechanism of failure.....	142
7.34.4	Avoiding the vulnerability or mitigating its effect.....	142
8	New vulnerabilities.....	143
8.1	General.....	143
8.2	Modifying constants [UJO].....	143
8.2.1	Description of application vulnerability.....	143
8.2.2	Cross reference.....	143
8.2.3	Mechanism of failure.....	143
8.2.4	Applicable language characteristics.....	144
8.2.5	Avoiding the vulnerability or mitigating its effects.....	144
8.2.6	Implications for language design and evolution.....	144
Annex A (informative) Vulnerability taxonomy and list.....		145
Annex B (informative) Selected guidance to language designers.....		153
Annex C (informative) Language-specific vulnerability template.....		155
Bibliography.....		158
Index.....		161

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document can be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents) or the IEC list of patent declarations received (see <http://patents.iec.ch>).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 22, *Programming languages, their environments and system software interfaces*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

This first edition cancels and replaces ISO IEC TR 24772:2013, which has been split into several parts.

A list of all parts in the ISO/IEC 24772 series can be found on the ISO website.

Introduction

All programming languages contain constructs that are incompletely specified, exhibit undefined behaviour, are implementation-dependent, or are difficult to use correctly. The use of those constructs can therefore give rise to *vulnerabilities*, as a result of which software programs can execute differently than intended by the writer. In some cases, these vulnerabilities can endanger the safety of a system or be exploited by attackers to compromise the security or privacy of a system.

This document provides users of programming languages with a language-independent overview of potential vulnerabilities in their usage and ways to avoid or mitigate them. Other parts of the ISO/IEC 24772 series describe how the general observations apply to specific languages.

This document is intended to provide guidance spanning multiple programming languages, so that application developers will be better able to avoid the programming constructs that lead to vulnerabilities in software written in their chosen language and their attendant consequences. This guidance can also be used by developers to select source code evaluation tools that can discover and eliminate some constructs that could lead to vulnerabilities in their software or to select a programming language that avoids anticipated problems.

The intended audience for this document are those who are concerned with assuring the predictable execution of the software of their system; that is, those who are developing, qualifying, or maintaining a software system and need to avoid language constructs that can cause the software to execute in a manner other than intended.

Developers of applications that have clear safety, security or mission-criticality requirements are expected to be aware of the risks associated with their code and can use this document to ensure that their development practices address the issues presented by the chosen programming languages, for example by subsetting or providing coding guidelines.

Specific audiences for this document include in particular developers, maintainers and regulators of:

- safety-critical applications that can cause loss of life, human injury, or damage to the environment;
- security-critical applications that need to ensure properties of confidentiality, integrity, and availability;
- mission-critical applications that need to avoid loss or damage to property or finance;
- business-critical applications where correct operation is essential to the successful operation of the business;
- scientific, modelling and simulation applications that require high confidence in the results of possibly complex, expensive and extended calculation.

However, it should not be assumed that other developers can ignore this document. A weakness in a non-critical application can provide the route by which an attacker gains control of a system or otherwise disrupts co-hosted applications that are critical. It is hoped that all developers would use this document to ensure that common vulnerabilities are removed or at least minimized from all applications.

While this document does not discuss specification or design issues, there is recognition that boundaries among the various activities are not clear-cut. This document seeks to avoid the debate about where low-level design ends and implementation begins by treating selected issues that some can consider design issues rather than coding issues.

It should be noted that this document is inherently incomplete. It is not possible to provide a complete list of programming language vulnerabilities because new weaknesses are discovered continually. Any such report can only describe those that have been found, characterized, and determined to have sufficient probability and consequence.

Programming languages — Guidance to avoiding vulnerabilities in programming languages —

Part 1: Language-independent guidance

1 Scope

This document specifies software programming language vulnerabilities to be avoided in the development of systems where assured behaviour is required for security, safety, mission-critical and business-critical software. Language-specific descriptions of these vulnerabilities are provided in other parts of the ISO/IEC 24772 series.

It is applicable to the software developed, reviewed, or maintained for any application.

This document does not address software engineering and management issues such as how to design and implement programs, use configuration management tools, use managerial processes, and perform process improvement. Furthermore, the specification of properties and applications to be assured are not treated.

Vulnerabilities are described in a generic manner that is applicable to a broad range of programming languages.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 2382, *Information technology — Vocabulary*

ISO 80000-2, *Quantities and units — Part 2: Mathematics*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 2382, ISO 80000-2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 Terms related to communication

3.1.1 protocol

set of rules and supporting structures for the interaction of threads

Note 1 to entry: A protocol can be tightly embedded and rely on data in memory and hardware to control interaction of threads or can be applied to more loosely coupled arrangements, such as message communication spanning networks and computer systems.