.e*.in) ,or -eri,ica.ion o, co ' ;le% cha**i*-con.rol *9*.e ' *₊ 3he ' e.hod* are deri-ed ,ro '
co ' ;u.er-)a ' e ;rinci;le* and re)ard .he *9*.e ' under .e*. a* an o;;onen. .ha. i* de,ea.ed <hen
.he *;eci,ica.ion i* -iola.ed₊ 3he ' e.hodolo)9 i* de ' on*.ra.ed on an au.o-codin) i ' ;le ' en.a.ion
o, a 5rake-5lendin) ,unc.ion ,or a hea-9 -ehicle, in co ' 5ina.ion <i.h a *i ' ula.ion ' odel
i ' ;le ' en.ed in Modelica₊ I. i* *ho<n .ha. a -a*. nu ' 5er o, *cenario* can 5e anal9=ed <i.h
' odera.e ' anual e,,or., and .ha. re*ul.* corre*;ondin) .o hi)h-co-era)e $MEA › $3A;nu*ae *a,e

;ro.o.9;e .e*.in)₊ 3he ' anual in-ol-e ' en. i* .i ' e-
con*u ' in) and li ' i.* .he nu ' 5er o, ca*e* .ha. can 5e
in-e*.i)a.ed and .e*.ed, and .he -eri,ica.ion ;roce** i* al*o
-er9 co*.l9₊ 3here are)rea. i ' ;ro-e ' en.* in e,,icienc9 and
co-era)e .o 5e)ained ,ro ' ,ur.her au.o ' a.in) .he*e
;rocedure*₊ 3he hu ' an in.er-en.ion i* al*o a *ource o,
error .ha. ' a9 5e reduced 59 au.o ' a.ion₊ Ano.her i**ue i*
.ha. -eri,ica.ion .e*.in) u*uall9 i* a;;lied a. la.er ;ha*e* in
.he de*i)n ;roce**, and ;ro5le ' * .ha. are iden.i,ied in .he*e
.e*.* ' a9 re:uire lar)e and e%;en*i-e *.e;* 5ack₊ i
?eri,ica.ion .e*.in) 5a*ed on ' odel* or *o,.<are ' a9 5e
a;;lied a. earlier ;ha*e* and ;ro5le ' * ' a9 .hu* 5e
iden.i,ied earlier₊

    3he co ' 5ina.ion o, a .ool .ha. au.o ' a.icall9 ;roduce*

and relia5le ;er,or ' ance a. a rea*ona5le co*.₊

    3radi.ional con.rol-de*i)n ' e.hod* ,ocu* on ro5u*.
;er,or ' ance and *.a5ili.9 in .er ' * o, ' odel uncer.ain.9 and
di*.ur5ance* in clo*ed-loo; *9*.e ' *₊ $or .he co ' ;le%
a))re)a.e o, -ehicle con.rol ,unc.ion*, .he .radi.ional
' e.hod* can onl9 5e a;;lica5le on *u5*e.* o, .he .o.al
9.e ', and ' u*. 5e co ' 5ined <i.h o.her ' e.hod* in order
.o anal9=e)lo5al ro5u*. and *uch co ' ;le%i.9 .ha. ,or ' al

-eri,ica.ion o, .he de*i)n i* ;rac.icall9 i ' ;o**i5le₊ In*.ead,
.he *9*.e ' ' u*. 5e *u5/ec.ed .o -eri,ica.ion .e*.in) <i.h a
*u,,icien. co-era)e .o 9ield con,idence in *a,e.9 and
a-aila5ili.9₊ Like<i*e, .he anal9*i* o, *9*.e ' ;er,or ' ance
under ;o**i5le ,aul. *cenario* ' u*. 5e anal9=ed 59 .e*.in)
ra.her .han ;roo,₊

    3he -eri,ica.ion .e*.in) in-ol-e* .he anal9*i* o, a -a*.
nu ' 5er o, *cenario* *elec.ed in a *9*.e ' a.ic <a9₊ 3hi*
<ork i* co ' ' onl9 done ' anuall9 .o a lar)e e%.en. in
de*i)n re-i*ion*, hard<are-in-.he-loo; ΛϬILℬ ri)*, and

;roo,-5a*ed

.he .ool and ' e.hod ,or au3

3

-&$H.

$est Scenario

3he .e*. con*i*.* o, a dri-er .ha. 5rake* and *.eer* .he -ehicle. 4ear *hi,.in) i* 'ade au.o'a.icall9. 3he Dri-er can)i-e in;u.* accordin) .o .he .a5le 5elo<.

Drivers

"a#e	$nit	%alues
/ ra,e Pedal Position (0 to (	'	>0! 0&(9! 0&-! 0&*9?
Steerin. A heel An.le	rad	>0! 0&9?

6&V.H'C0. M*+.0

3o .e*. and -eri,9 .he 5rake-5lendin) ,unc.ion i. i* nece**ar9 .o *i'ula.e i.* o;era.in) en-iron'en. includin) .he .rac.or .o<in)--ehicle, a dri-er, and .he road. 3hi* en-iron'en. 'u*. ;roduce reali*.ic re*;on*e* .o .he con.rol ac.ion* co''u.ed 59 .he ,unc.ion. $or .hi* ;ur;o*e a 'odel i* 5uil. u*in) .he Modelica-5a*ed .ool* D9'ola and ?ehicle D9na'ic* Li5rar9 , and . Modelica i* an o;en-*;eci,ica.ion hi)h-le-el o5/ec.-orien.ed and co''ponen.-5a*ed lan)ua)e de*i)ned ,or 'ul.i-do'ain 'odelin) ,or *i'ula.ion o, co';le% *9*.e'*. Modelica i* de*i)ned ,or acau*al and e:ua.ion 5a*ed 'odelin), <hich 'ake* .he 'odel* hi)hl9 reada5le and reu*a5le. An ou.*.andin) ,ea.ure o, Modelica-5a*ed *olu.ion* in .he con.e%. o, -eri,ica.ion .e*.in) i* .he e%;o*ed and 'odi,ia5le 'odel *ource code in co'5ina.ion <i.h .he hi)h-le-el 'odel de*cri;.ion*. I. i* ;o**i5le .o -ie< and 'odi,9 or e%.end .he i';le'en.a.ion o, co';onen. and *9*.e' 'odel*. In .hi* <a9 in*.ru'en.* can 5e added .o .he -ehicle 'odel, *uch a* *en*or in*.ru'en.* ,or cri.eria e-alua.ion, and in*.ru'en.* ,or in;u. e%ci.a.ion and ;ara'e.er -aria.ion* .o de*cri5e o;era.in) condi.ion*, .olerance -aria.ion*, and ,aul.

in/ec.ion. $i)ure 8 *ho<* .he .rac.or 'odel and .he 'ain ;o<er.rain, 5rake*, and cha**i* *u5*9*.e'*, and .he in*.ru'en.* u*ed 59 3e*.Wea-er. 3he ;o<er.rain 'odel include* a)ear5o%, en)ine re.arder, dri-eline re.arder, and dri-eline <i.h ,inal)ear and di,,eren.ial. 3he 5rake *u5*9*.e' include* co';onen.* ,or *er-ice di*k-5rake* <i.h ABS. 3he cha**i* con.ain* ,ron. and rear a%le*, <i.h *.eerin), ca5in, ,ra'e, and <heel*. 3he -ehicle run* on an in,ini.e ;lane <i.h con,i)ura5le inclina.ion and *ur,ace ,ric.ion. 3he 'odel con.ain* a5ou. *e-en .hou*and e:ua.ion* and "3 con.inuou* *.a.e*. I. i* .ran*la.ed in.o @-code u*in) .he D9'ola inline .ra;e=oid in.e)ra.ion ,ea.ure ,or)enera.ion o, e,,icien. real-.i'e *i'ula.ion code. I. i* .hen co';iled and linked in.o a DLL can

. Ö"a`a#

' oni.ored *a,e.9 ha=ard* and .he ;o**i5le ,aul.* .ha. could 5e rela.ed .o .he '+ 3he .ool chain hel;ed .o anal9=e, in de.ail, .he cau*e-e,,ec. rela.ion*hi;, an o.her<i*e e%.re ' el9 di,,icul. en.er;ri*e, i, ;o**i5le a. all, con*iderin) .he co ' ;le%i.9 and .he a ' oun. o, *o,.<are ,unc.ion* in-ol-ed+ G, cour*e, .he *i ' ula.ion re*ul.* need .o 5e e-alua.ed and co ' ;le ' en.ed 59 .he anal9*i* o, e%;erienced en)ineer*+ A* a *econd *.e;, .he .ool chain ;re*en.ed here can 5e u*ed .o -eri,9 .ha. .he coun.er ' ea*ure* de*i)ned .o i ' ;ro-e *9*.e ' *a,e.9 are *ucce**,ul+

$i)ure # *ho<* a ;iece o, a co-era)e re;or.)enera.ed 59 3e*.Wea-er, ,or anal9*i* o, .he *in)le ,aul. e-en.*+

inserted faults	Brk'dl'osC#d(S&	speed
@rv2etrdAct)+0).ainEomission	no)#ra,e	((0%20
	little)#ra,e	(0%(0
	some)#ra,e	(0%(0
	much)#ra,e	(0%(0
		((0%20
En.2etrdAct)+0).ainEomission	no)#ra,e	(0%(0
		((0%20
	little)#ra,e	(0%(0
		((0%20
	some)#ra,e	(0%(0
		((0%20
	much)#ra,e	(0%(0
		((0%20
D	D	D
driveBine2etarderA5le+or0ueShareCodeE omission	no)#ra,e	(0%(0
		((0%20
	little)#ra,e	(0%(0
		((0%20
	some)#ra,e	(0%(0
		((0%20
	much)#ra,e	(0%(0
		((0%20

$i)ure #+ Su5*eeed,#p*er.ed ,aul.* A3 ou. o, 33ß+

a

Mo*. o, .he en.ire cro** ;roduc. o, in*er.ed ,aul.*, 5rake ;edal ;o*i.ion and *;eed* are e-alua.ed - onl9 a ,e< *;eed co ' 5ina.ion* are ' i**in)+ 3he *;eed i* no. direc.l9 con.rolled, 5u. a con*e:uence o, .he 5rake ;edal ;o*i.ion+

6@i.he

) o#ustness Study

$or .he ro5u*.ne** *.ud9, .he e,,ec. o, co ' 5ined -aria.ion* o, -ehicle ;ara ' e.er*, road condi.ion*, and dri-er in;u. *e:uence are in-e*.i)a.ed+ 3he *earch *;ace i* .hen o, cour*e enor ' ou* and i. i* i ' ;lau*i5le .ha. co ' ;le.ene** can 5e achie-ed+ Ne-er.hele**, .he ' a/or re*ul. i* .ha. o,.en cri.ical *i)nal* and ;ara ' e.er* can 5e e,,ec.i-el9 iden.i,ied+ 3hu*, al*o .hi* kind o, *.ud9 can re-eal e%i*.in) ri*k* or ro5u*.ne** <eakne**e*, .ha. need .efRelddRBfBBrBa0hdaGRe*7eSfa.@