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Transmission systems, su)h as !CTs, re3uire systemati) test and validation methods in order to %uarantee)orre)tness and 3uality despite shorter development times and in)reasin%)omple4ity. There*ore, durin% the development o* a ne5 dual)lut)h transmission at 'I(, a pro)ess *or e4tensive test and optimi6ation o* the)ontrol so*t5are has ,een adopted. (or this, system)orre)tness and 3uality)riteria are evaluated *or thousands o* simulated test s)enarios 7drivin% maneuvers8. $ro,lems and system 5ea# points are identi*ied and)orre)ted as early as possi,le and the pro)ess is repeated a*ter ea)h)orre)tion or system)han%e. The tool Test9eaver :2; *rom 2Troni) 5as used *or the systemati) %eneration and evaluation o* the test s)enarios. This allo5s a)hievin% hi%h test)overa%e 5ith minimal test spe)i*i)ation e**ort. This e4tensive test pro)ess drives and a))elerates the optimisation o* the)ontrol so*t5are. Beside 1I< tests also intensive SI<, -I< and tests 5ith the real hard5are)omponents in the loop must ,e per*ormed in order to %uarantee the *un)tionality o* the automati)ally %enerated)ode, the proper *un)tionality o* the TC= in)ludin% ele)troni)s and CA")ommuni)ation, and the ro,ustness o* the so*t5are *un)tions under real operatin%)onditions :>;.

Transmission systems are under)ontinuous improvement 5ith respe)t to e**i)ien)y, ro,ustness,)osts and)om*ort. 1any o* these re3uirements have to ,e addressed also ,y the transmission)ontrol so*t5are, 5hi)h is ,e)omin% more and more intelli%ent. 1any drivin%)onditions have to ,e dete)ted *ast and relia,ly. Spe)i*i), optimi6ed a)tions and)ontrol strate%ies have to ,e per*ormed in order to a)hieve the optimum ,alan)e ,et5een o*ten)on t~ :$CC0the hu%e num,er o* di**erin% situations tha

The so*t5are o* the ne5 'I(!CT is developed usin% a model-,ased development pro)ess 5ith Simulin# and Tar%et<in#. The)omplete)ontrol so*t5are model)an ,e simulated in)losed-loop 5ith a realisti) plant model developed also in Simulin# - in)ludin% transmission hydrauli)s, me)han-

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mer)ial $C. The simulation in)ludes, ,eside the)ontrol model and the plant model, also several)orre)tness and 3uality o,servers implemented in Simulin#. Test9eaver then)ontrols and evaluates the simulation runs. Thousands o* s)enarios are automati)ally %enerated and assessed in a rea)tive loop in 5hi)h Test9eaver a)tively attempts to rea)h all possi,le system states 5ith at least one s)enario and to *ind s)enarios 5ith)orre)tness or 3uality pro,lems. (or instan)e, it 5ill try to rea)h all transmission shi*ts, simple 7e.%. @-A8 and multiple 7e.%. B-@8, 5ith many di**erin% speed and tor3ue loads, 5ith di**erin% street slopes, 5ith and 5ithout ,ra#in%, 5ith or 5ithout)han-

%in% the a))eleration pedal durin% the shi*t, 5ith ideal sensor models or 5ith a)tive in(e)tion o*

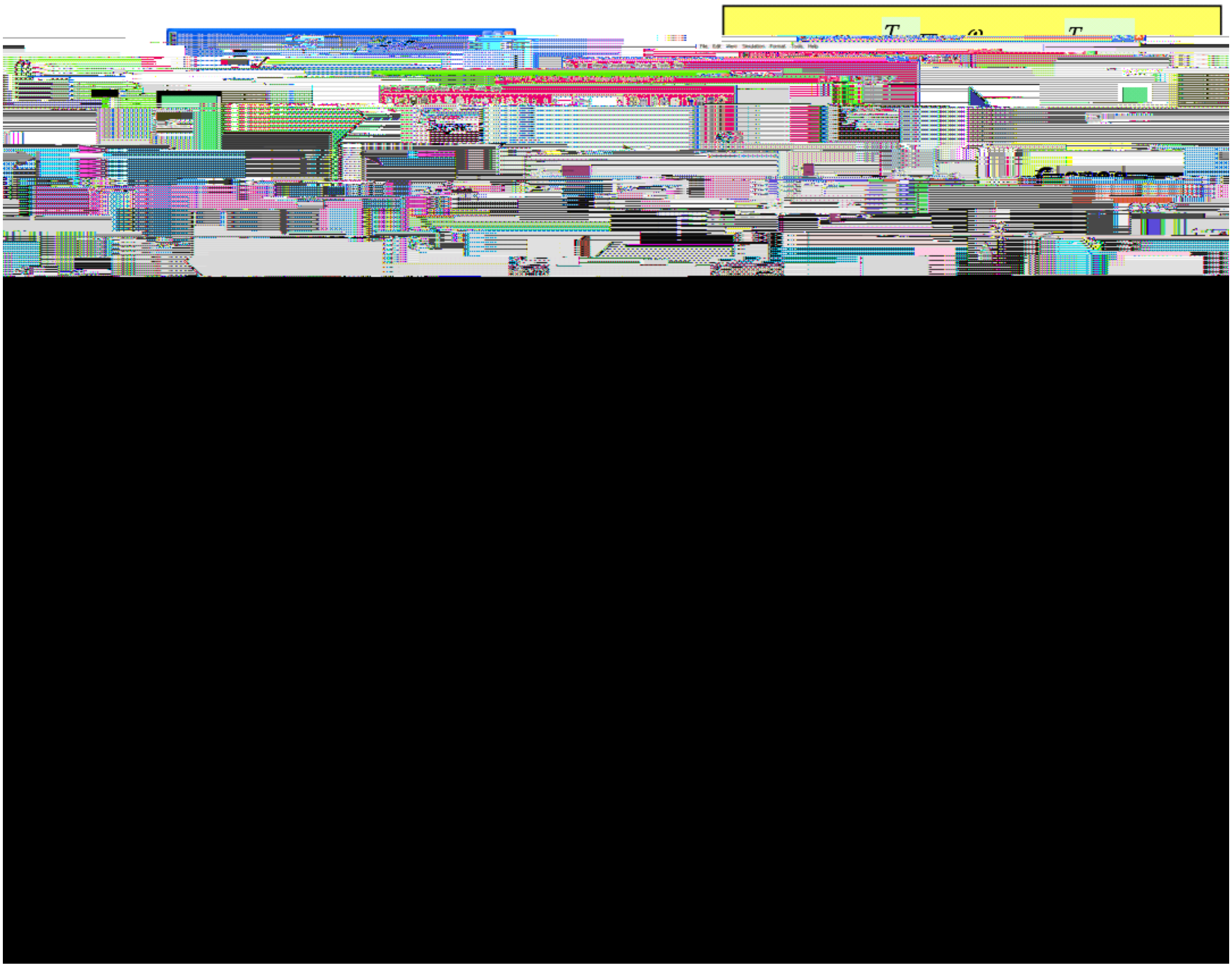

Figure 2: Model- ased function development

The ne4t phase in the development pro)ess is the *un)tion prototypin% phase, 5here the developed al%orithms are tested and validated 5ith the real hard5are)omponents. (or this purpose rapid prototypin% tools *rom dS$ACG are used. (rom the Simulin# modules *or the *un)tional and sa*ety so*t5are, C-)ode is automati)ally %enerated usin% ?eal Time 9or#shop F 1ath5or#s and ?eal Time Inter*a)e F dS$ACG. The prototype)ode)an then run in a prototype)ontroller *rom dS$ACG. This tool)hain is very *le4i,le and minimises the time to prototype tests, sin)e the en%ineers)an)on)entrate purely on the *un)tion development.

In the same development environment also the em,edded)ode %eneration is inte%rated. =sin% the same Simulin# modules and 5ith Tar%et <in# *rom dS$ACG a 100 I automated em,edded)ode *or the tar%et TC= is %enerated. Based on Tar%et <in#, So*t5are-In-the-<oop tests 7SI<8 are possi,le. In the SI< tests the %enerated em,edded)ode is tested in)losed loop simulation usin% the same po5ertrain model. The di**eren)es ,et5een the *un)tional Simulin# models and the %enerated)ode are analy6ed in order to evaluate the e**i)ien)y o* the %enerated)ode. The num,er o* per*ormed test)ases, sele)ted *rom a %enerated data ,ase, depends on the tar%et test)overa%e.

The %enerated em,edded)ode o* the *un)tional so*t5are is inte%rated 5ith the so*t5are *rom the TC= supplier. This)ode)ontains the operatin% system, the BIDS and the *ault monitorin% *un)tions o* the ele)troni) system. This)onsists o* the mi)ro)ontroller, the sensors and the a)tuators o* the hydrauli) module. The)omplete em,edded)ode is then *lashed in the produ)tion TC=. The so*t5are inte%ration and the)orre)t operation o* the *un)tional)ode on the tar%et pro)essor is)he)#ed and validated in a -I< system. In the -I< test the drivin% situations)an ,e simulated usin% a%ain the same po5ertrain model as in 1I< and SI<. (urthermore, some)riti)al situations, su)h as those)aused ,y ele)tri)al *ailures, are simulated and the ,ehaviour o* the TC= is validated. The tested TC= is then released *or vehi)le use and *or the *inal)ali,ration pro)edure J *or more details see :>;.

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The so*t5are development pro)ess des)ri,ed a,ove)onsists o* di**erent steps 5here the test and validation o* the)urrent so*t5are must ,e done. In the *ollo5in% se)tions the test pro)edures 5ill

The system states rea)hed durin% a test are reported usin% -T1< ta,les. Eia *urther lin#s, des)riptions are provided a,out ho5 ea)h state)an ,e rea)hed. Based on this in*ormation, at the end o* the test, the s)enarios 5ith pro,lems)an ,e replayed in simulation ,y the development en%ineers *or detailed analysis and de,u%%in%. 1ore details a,out the tool)an ,e *ound in :2;.

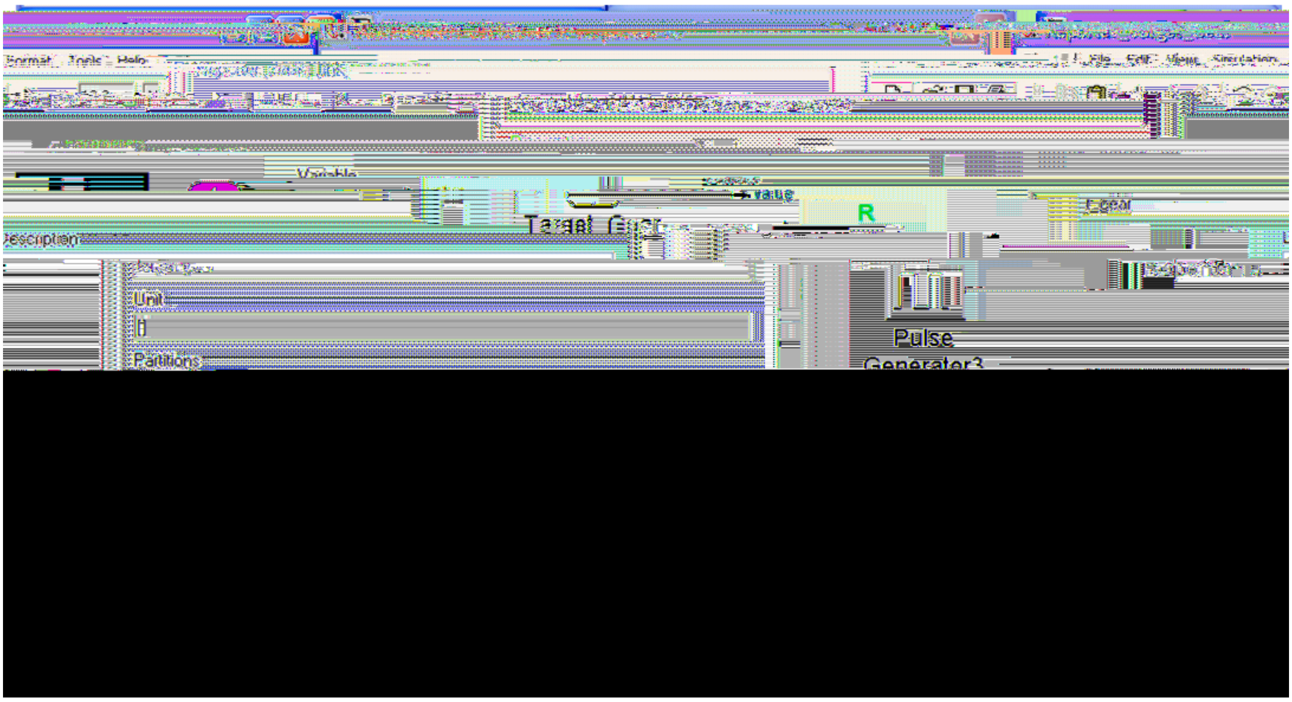

Figure !: The definition of a reporter for Test "eaver

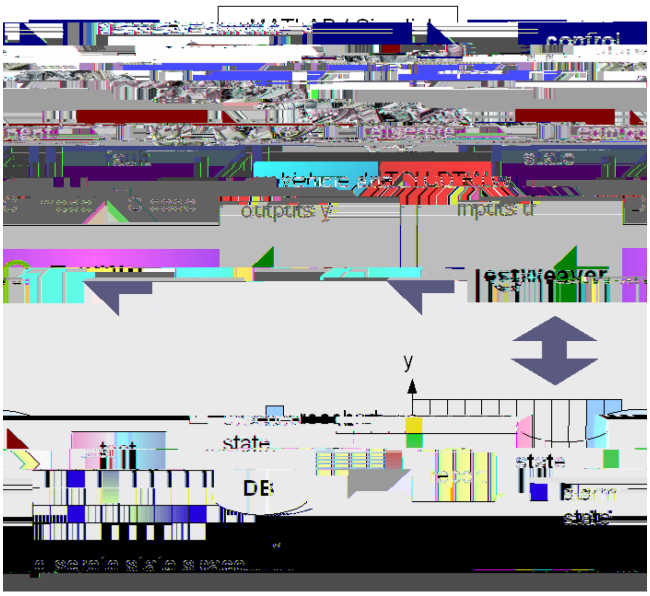

Figure #: $utomatic scenario generation and assessment

4.2

The simulation started ,y Test9eaver in)ludes: the !CT)ontrol so*t5are, the po5ertrain model, the driver's input ,lo)#, 5here the)hoosers o* Test9eaver are inserted, and a s)ope ,lo)# 5here di**erent state varia,les and the reporter ,lo)#s o* Test9eaver are inte%rated. Additional *un)tions)an ,e added, ,eside the *un)tional so*t5are and the po5ertrain model, and)an ,e used as 3uality o,servers and *or a ,etter s)enario assessment durin% the tests.

The si%nals)ontrolled ,y Test 9 eaver in this appli)ation in)lude the i%nition, the a))eleration ped-al, the ,ra#e pedal, the shi*t lever pa0pe*tpe

The Simulin# model that)ontains the !CT)ontrol so*t5are, the po5ertrain model, the driver model and the s)opes are)ompiled 5ith ?eal-Time 9or#shop *or *aster simulation. !urin% s)enario %eneration 5ith Test9eaver the)ompiled model is used. This simulation runs a,out 20 times *aster than real time[1] on a normal $C. This 5ay in 1B hours runnin% time more than 1@.000 s)enarios are %enerated.

Su , se3uently,

Figure): *m edded code +ualit(control and coverage

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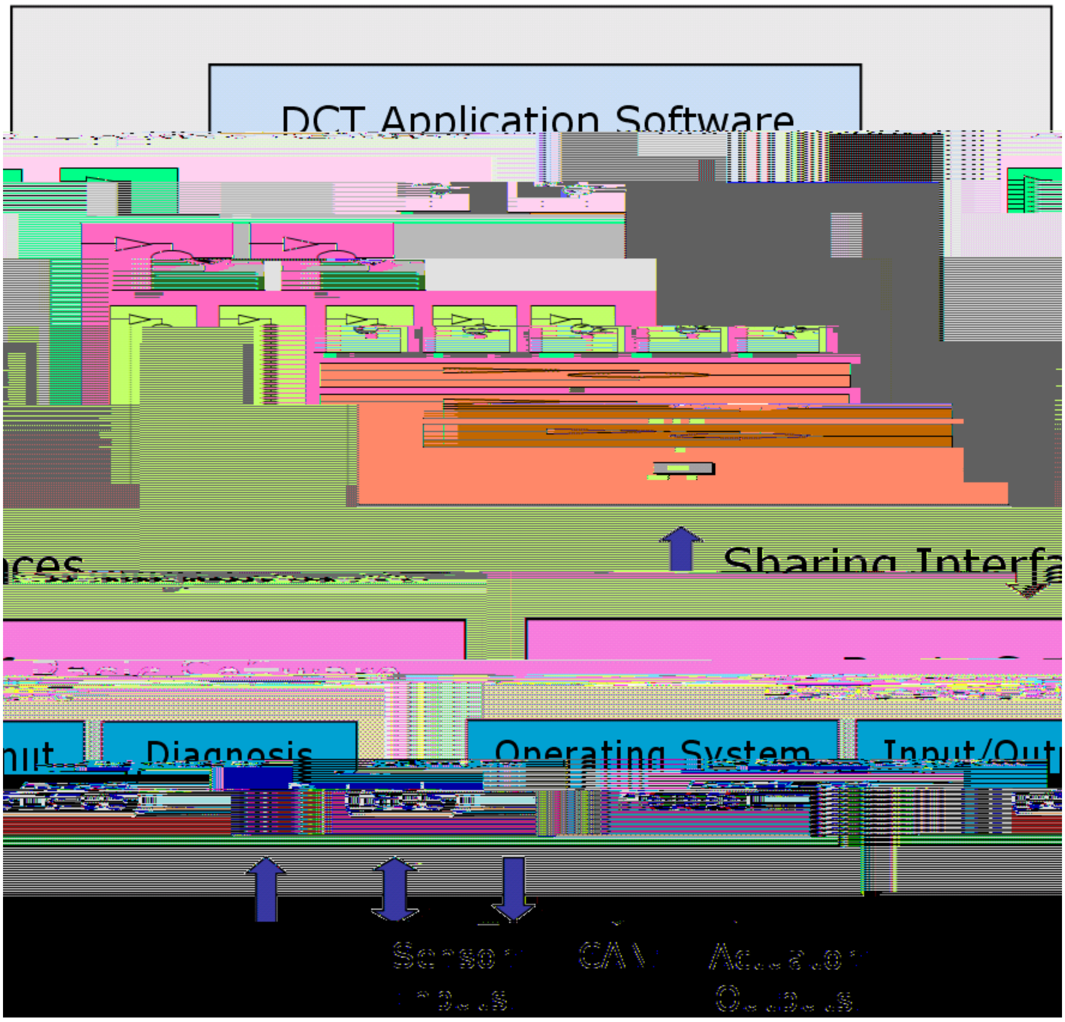
DCT Application Software
Diagnosis
Operating System

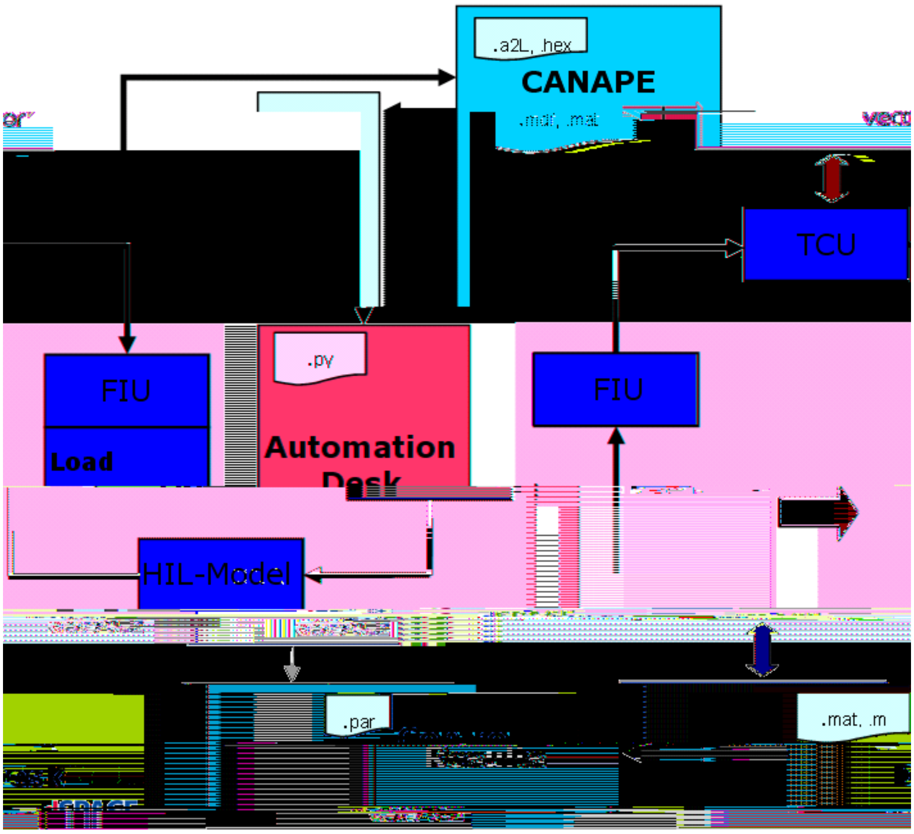

Figure .: -ignal flow during /01 testing

Sin)e the)ommuni)ation o* the di**erent modules o* the -I< environment is 3uite)ompli)ated, as)an ,e seen in the *i%ure a,ove, some intelli%ent)ommuni)ation te)hni3ues are used in order to improve the -I< per*orman)e. (or this reason the 5hole simulation is)ontrolled ,y the Automation !es#. Automation !es# per*orms tests in loops. 1easured data *rom the TC= and the po5ertrain model runnin% on -I< are re3uested 5hen a test is *inished. !ata *rom the TC=)ali,ration tool CA"A$G 7Ee)tor In*ormati#8 are)olle)ted and a s)ript runnin% in 1atla, is automati)ally started 7not sho5n in the pi)ture8. This s)ript)ontains evaluation)riteria *or the e4e)uted test and)an de)ide i* the test is passed or not. This is ,ased on e4istin%, prede*ined)riteria *rom the *ailure spe)i*i)ation list. Automation !es# is also a,le to erase the *ailure memory o* the TC= 7via CA"A$G8 in order to)ontinue 5ith the ne4t test loop. This 5ay the test e4e)ution and the test evaluation are done automati)ally. The user only needs to read the test report and to *or5ard the possi,le *ailures to the *un)tion developers.

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The)omple4ity o* transmission systems is steadily in)reasin% due to %ro5in% mar#et e4pe)tations re%ardin% e**i)ien)y, a%ility and)om*ort. The)orrespondin% development times are)onstantly shortened, 5hile simultaneously #eepin% hi%h 3uality standards. The %ro5in%)omple4ity and limited resour)es impose an in)reasin% pressure on ,oth DG1s and suppliers to *urther improve the development pro)ess. In parti)ular, also the test and validation have to ,e)ome more relia,le and more)ost-e**e)tive.

(or the ne5 !CT development pro0e)t 'I(has adopted a)omprehensive so*t5are test and validation method. Thousands o* drivin% maneuvers are autonomously %enerated, e4e)uted and evaluated usin% simulation. !ue to the hi%h de%ree o* automation, the test e**ort spent ,y the development en%ineers is si%ni*i)antly redu)ed, 5hile, at the same time, the test)overa%e is si%ni*i)antly in)reased. (uture improvement dire)tions re%ard the appli)ation o* the s)enario %eneration and evaluation *or tests dire)tly on SI< and -I< plat*orms. 2Troni) has re)ently e4tended its produ)t ran%e to)over these re3uirements.

(urthermore, ,eside the tests done in the simulation environment, very important)omplementary tests are done durin% the *un)tion prototypin% phase. Tests 5ith real hard5are)omponents must ,e done in order to ensure the ro,ustness o* the so*t5are *un)tions under all environment and transmission states. !urin% the development o* the 'I(!CT a lar%e num,er o* tests on test ri%s has ,een per*ormed in order to validate the proper and ro,ust *un)tionin% o* the transmission. The intensively tested so*t5are a*ter the prototypin% phase represents a %ood startin% ,asis *or the em-,edded)ode %eneration *or the produ)tion TC=. The C-)ode %enerated *rom the Simulin# ,lo)# dia%rams is su,se3uently tested in SI< and su**i)ient)ode)overa%e is %uaranteed usin% test)ases *rom the %enerated test data ,ase. In this phase some *urther development is needed, sin)e the e4e)ution time o* the tests usin% the %enerated C-)ode in)losed loop 5ith the po5ertrain model is relatively lon%. -I< tests are done at the end o* the pro)ess 5ith the produ)tion TC= and the inte%rated so*t5are. These tests are very important in order to %uarantee the proper inte%ration o* the di**erent so*t5are parts and the *un)tion o* the)ommuni)ation inter*a)es. !urin% -I< tests, the *un)tionality o* the)omplete TC=, in)ludin% the rea)tion to ele)tri)al *ailures, is tested. This)on