A Appendix: Formalised Requirements in FRETISH

Table 1: FRETISH Requirements.

Req ID	FRETISH
CONT1	Controller shall always satisfy StartUpMode | SelfTestMode | StandbyMode | PCVMode | PSVMode | FailSafeMode
CONT1_1	in StartUpMode Controller shall eventually satisfy initStart & (initDone | (initFail & OutOfServiceWarning & FailSafeMode))
CONT1_3	in StandbyMode Controller shall always satisfy ventilationOff & inValveClose & outValveOpen
CONT1_6	in FailSafeMode Controller shall always satisfy inValveClose & outValveOpen
CONT2	if powerOff & !powerButton Controller shall always satisfy !StartUpMode
CONT3	in StartUpMode when initDone Controller shall at the next timepoint satisfy SelfTestMode
CONT4	in SelfTestMode if selfTestPassed | GUIResumeRequest Controller shall at the next timepoint satisfy StandbyMode
CONT5	in StandbyMode if PSVModeSelected Controller shall at the next timepoint satisfy PSVMode
CONT6	in StandbyMode if PCVModeSelected Controller shall at the next timepoint satisfy PCVMode
CONT7	in PCVMode if inspiratoryPhaseEnd & PSVModeSelected Controller shall at the next timepoint satisfy ventilating & PSVMode
CONT8	in PCVMode if stopVentilation Controller shall at the next timepoint satisfy StandbyMode
CONT9	in PSVMode when breathingTime >= apneaLagTime Controller shall at the next timepoint satisfy PCVMode & RR = RR_AP & P_insp = P_inspAP & ItoE = ItoE_AP
CONT10	in PSVMode if stopVentilation Controller shall at the next timepoint satisfy StandbyMode
CONT11	if powerOff Controller shall at the next timepoint satisfy FinalState
CONT11_1	in FinalState Controller shall eventually satisfy parametersStored & off
CONT12	in StartUpMode Controller shall eventually satisfy defaultParamsLoaded
CONT13	in StartUpMode Controller shall eventually satisfy checkCommsSensors & checkCommsValves
CONT14	in StartUpMode Controller shall eventually satisfy checkCommsGUI
CONT15	in StartUpMode if pressureSensorRetries >= 5 & (pressureSensorConnFailure | pressureSensorError) Controller shall at the next timepoint satisfy FailSafeMode
CONT16	in StartUpMode if ADCRetries >= 5 & (ADCConnFailure | ADCError) Controller shall at the next timepoint satisfy FailSafeMode

CONT18	in SelfTestMode Controller shall eventually satisfy selfTestPassed | selfTestFailed
CONT19	in SelfTestMode if SelfTestFail Controller shall until off satisfy !StandbyMode & !ventilating
CONT20	in PCVMode Controller shall always satisfy breathingCycleTime = 1/RR_PCV & ExpiratoryTime = breathingCycleTime / (1+ItoE_PCV)
CONT21	in PCVMode when BreathingCycleStart Controller shall at the next timepoint satisfy inspiratoryPhaseStart
CONT22	in PCVMode Controller shall always satisfy inspiratoryTime = 60*(ItoE_PCV/(RR_PCV * (1 + ItoE_PCV)))
CONT23	while PCVMode & inspiratoryPauseButton when inspiratoryPhaseEnd Controller shall for 40 seconds satisfy (inspiratoryPauseButton => inValveClose & outValveClose)
CONT24	while PCVMode & RMButton when inspiratoryPhaseEnd Controller shall at the next timepoint satisfy RM
CONT25	in PCVMode Controller shall always satisfy (breathingCycleDone | patientBreathingRequest) => (breathingCycleStart & inspiratoryPhaseStart)
CONT26	while PCVMode when dropPAW > ITS_PCV Controller shall at the next timepoint satisfy patientBreathingRequest
CONT27	in PCVMode when expiratoryPauseButton & ExpiratoryPhaseEnd & !patientBreathingRequest Controller shall until buttonUnPressOr60Seconds satisfy expirationPhaseEnd & inValveClose & outValveClose
CONT28	in PCVMode Controller shall always satisfy P_insp = P_inspPCV
CONT30	in PSVMode when BreathingCycleStart Controller shall at the next timepoint satisfy inspiratoryPhaseStart
CONT32	in PSVMode Controller shall until (P_insp >= MaxP_insp | inspClock >= inspiratoryTime) satisfy inspiratoryPhase
CONT33	in PSVMode when V_E < ExpiratoryTriggerSensitivity*PeakV_E Controller shall at the next timepoint satisfy expirationPhaseStart
CONT34	while PSVMode & inspiratoryPauseButton when inspiratoryPhaseEnd Controller shall for 40 seconds satisfy (inspiratoryPauseButton => inValveClose & outValveClose)
CONT35	while PSVMode & RMButton when inspiratoryPhaseEnd Controller shall at the next timepoint satisfy RM
CONT36_1	while PSVMode & expiratoryPhase when dropPAW > ITS_PSV Controller shall at the next timepoint satisfy patientBreathingRequest
CONT36_2	while PSVMode when expiratoryPauseButton & expClock <= apneaLagTime & !patientBreathingRequest Controller shall until buttonUnPressOr60Seconds satisfy expirationPhaseEnd & inValveClose & outValveClose
CONT36_3	in PSVMode Controller shall always satisfy minExpiratoryTime >= 0.4 & minExpiratoryTime <= 2 & (expiratoryPhase => minExpiratoryTime = inspClock/2)

CONT37	in PSVMode when expClock >= apneaLagTime Controller shall at the next timepoint satisfy apnea & PCVMode & RR = RR_AP & P_insp = P_inspAP & ItoE = ItoE_AP
CONT38	while StartUpMode | StandbyMode Controller shall always satisfy inValveClose & outValveOpen
CONT39	while inspiratoryPhase Controller shall always satisfy outValveClose & (PCVMode & !apnea => P_insp = P_isnpPCV) & (PSVMode => P_insp = P_inspPSV) & (PCVMode & apnea => P_insp = P_inspAP)
CONT40	while expiratoryState Controller shall always satisfy inValveClose & outValveOpen
CONT41	while (PCVMode | PSVMode) when inspiratoryPauseButton Controller shall eventually satisfy inspiratoryPause | !inspiratoryPauseButton
CONT41_1	while (PCVMode | PSVMode) & inspiratoryPauseButton when inspiratoryPhaseEnd Controller shall at the next timepoint satisfy (inspiratoryPauseButton => inspiratoryPause & inValveClose & outValveClose)
CONT41_2	when inspiratoryPause Controller shall after 40 seconds satisfy !inspiratoryPause & expirationPhaseStart
CONT42	while (PCVMode | PSVMode) when expiratoryPauseButton Controller shall eventually satisfy expiratoryPause | !expiratoryPauseButton
CONT42_1	while (PCVMode | PSVMode) & expiratoryPauseButton when expiratoryPhaseEnd Controller shall at the next timepoint satisfy (expiratoryPauseButton => expiratoryPause & inValveClose & outValveClose)
CONT42_2	when expiratoryPause Controller shall after 40 seconds satisfy !expiratoryPause & inspiratoryPhaseStart
CONT43	while (PCVMode | PSVMode) & RMButton & !inspiratoryPauseButton when inspiratoryPhaseEnd Controller shall at the next timepoint satisfy RM
CONT43_1	while RM if !RMButton Controller shall at the next timepoint satisfy !RM & expirationPhaseStart
CONT43_2	when RM Controller shall after 10 seconds satisfy !RM & expirationPhaseStart
CONT43_3	while RM Controller shall always satisfy outValveClose & inValveOpen
CONT44	if P_insp > MaxP_insp Controller shall at the next timepoint satisfy inspiratoryPhaseEnd & expirationPhaseStart
CONT45	when expirationPhaseStart Controller shall after 700 milliseconds satisfy monitorInhaleTrigger
CONT46	after FailSafeMode Controller shall until off satisfy !(StartUpMode | SelfTestMode | StandbyMode | PCVMode | PSVMode)
FUN4	System shall always satisfy StartUpMode | SelfTestMode | StandbyMode | PCVMode | PSVMode | FailSafeMode
FUN5	when powerButton & (breathingCircuitConnected & !(patientConnected) & airSupplyConnected & powerConnected) System shall at the next timepoint satisfy StartUpMode
FUN5_1	in StartUpMode System shall eventually satisfy initStart & checkCommsSensors & checkCommsValves & checkCommsGUI

FUN5_2	in StartUpMode System shall eventually satisfy initDone | (initFail & OutOfServiceWarning & FailSafeMode)
FUN5_3	System shall always satisfy (StartUpMode | SelfTestMode) -> !patientConnected
FUN6	in SelfTestMode System shall eventually satisfy selfTestPassed | selfTestFailed
FUN6_1	in SelfTestMode System shall eventually satisfy testPowerSwitchPass | testPowerSwitchFail | testPowerSwitchSkip
FUN6_2	in SelfTestMode System shall eventually satisfy testLeaksPass | testLeaksFail | testLeaksSkip
FUN6_3	in SelfTestMode System shall eventually satisfy testFl2Pass | testFl2Fail | testFl2Skip
FUN6_4	in SelfTestMode System shall eventually satisfy testPSExpPass | testPSExpFail | testPSExpSkip
FUN6_5	in SelfTestMode System shall eventually satisfy testOxygenSensorPass | testOxygenSensorFail | testOxygenSensorSkip
FUN6_6	in SelfTestMode System shall eventually satisfy testAlarmsPass | testAlarmsFail | testAlarmsSkip
FUN7	in SelfTestMode if selfTestFail System shall at the next timepoint satisfy OutOfServiceWarning & FailSafeMode
FUN8	System shall always satisfy logParams & saveLog & loadLog
FUN8_5	System shall always satisfy if user = operator then !eraseLog
FUN8_6	when ventilatorSettingsChanged System shall at the next timepoint satisfy logVentilatorSettings
FUN8_7	when alarmSettingsChanged System shall at the next timepoint satisfy logAlarmSettings
FUN8_8	when patientChanged System shall at the next timepoint satisfy logPatientChange
FUN8_9	when powerSupplyChanged System shall at the next timepoint satisfy logPowerSupply
FUN8_10	when preUseCheckDone System shall at the next timepoint satisfy logPreUseCheck
FUN8_11	System shall always satisfy logO2SensorUse
FUN8_12	System shall always satisfy logVentilationParams & logAlarmParams & logCalibrationParams
FUN9	when selfTestPassed System shall at the next timepoint satisfy startMonitoring & startReportingHealthParams & StandbyMode
FUN10	when startUpDone System shall eventually satisfy newPatient | resumeVentilation
FUN10_1	when newPatient System shall eventually satisfy patientAttributesEntered & SelfTestMode & ((testPowerSwitchPass & testLeaksPass & testFl2Pass & testPSExpPass & testOxygenSensorPass & testAlarmsPass) => selfTestPassed)
FUN10_2	when resumeVentilation System shall at the next timepoint satisfy loadLastParams

FUN10_3	when resumeVentilation System shall eventually satisfy SelfTestMode & (((testPowerSwitchPass | testPowerSwitchSkip) & (testLeaksPass | testLeaksSkip) & (testFl2Pass | testFl2Skip) & (testPSExpPass | testPSExpSkip) & (testOxygenSensorPass | testOxygenSensorSkip) & (testAlarmsPass | testAlarmsSkip)) => selfTestPassed)
FUN10_4	when selfTestPassed System shall at the next timepoint satisfy StandbyMode
FUN10_5	in StandbyMode System shall always satisfy ventilationOff & ventilationParmsAdjustable
FUN10_6	when off System shall after 15 minutes satisfy !resumeVentilation
FUN11	System shall always satisfy GBPS <= 5.2
FUN13	System shall always satisfy measureRR & displayRR
FUN14	System shall always satisfy measureO2% & displayO2%
FUN15	System shall always satisfy measurePSins
FUN16	System shall always satisfy measureTV & displayTV
FUN17	System shall always satisfy measureFl1 & display Fl1
FUN18	System shall always satisfy (if enableLeakCompensation then leakCompensation) | !leakCompensation
FUN18_1	System shall always satisfy (if enableLeakCompensation then leakCompensation) & (if disableLeakCompensation then (!leakCompensation & !enableLeakCompensation))
FUN18_2	when leakCompensationEnable if MinPEEPAlarm System shall at the next timepoint satisfy leakCompensationActive
FUN20	in PCVMode System shall always satisfy breathingCycleTime = 1/RR_PCV & ExpiratoryTime = breathingCycleTime / (1+ItoE_PCV)
FUN21	in PCVMode System shall always satisfy (breathingCycleDone | patientBreathingRequest) => breathingCycleStart
FUN21_1	when inspiratoryPressure < InhaleTriggerSensitivityPCV System shall at the next timepoint satisfy breathingCycleStart
FUN21_2	when patientBreathTrigger System shall at the next timepoint satisfy breathingTimerReset
FUN22	in PCVMode when RMButton System shall at the next timepoint satisfy RM
FUN23	in PCVMode when PSVModeSelected System shall at the next timepoint satisfy ventilating & PSVMode
FUN23_1	in PCVMode when PSVModeSelected System shall eventually satisfy confirmPSVParameters
FUN23_2	in PCVMode System shall always satisfy ((confirmPSVParameters & PSVMode) | (!confirmPSVParameters & PCVMode)) & ventilating
FUN23_3	in PCVMode when PSVModeSelected System shall at the next timepoint satisfy !(PCVInspTimeEnd & PSVMode)
FUN25	in PSVMode when inspiratoryPressure < InhaleTriggerSensitivityPSV System shall at the next timepoint satisfy breathingCycleStart
FUN26	in PSVMode when Fl1 < ExpiratoryTriggerSensitivity System shall at the next timepoint satisfy expirationPhaseStart

FUN27	in PSVMode when breathingTime >= apneaLagTime System shall at the next timepoint satisfy apnea
FUN27_1	if apnea System shall at the next timepoint satisfy apneaAlarm
FUN27_2	if apnea System shall at the next timepoint satisfy PCVMode & RR = RR_AP & P_insp = P_inspAP & ItoE = ItoE_AP
FUN28	when expiratoryPauseButton & (ExpiratoryPhaseEnd) System shall until buttonUnPressOr60Seconds satisfy expirationPhaseEnd & inValveClose & outValveClose
FUN29	while inspiratoryPauseButton when (inspiratoryPhaseEnd) System shall for 40 seconds satisfy (inspiratoryPauseButton => inValveClose & outValveClose)
FUN30	System shall always satisfy if StartUpMode then (if newPatient then SelfTestMode & if !newPatient then StandbyMode) & if SelfTestMode then (if selfTestPassed then StandbyMode) & if StandbyMode then (if startPCV then PCVMode & if startPSV then PSVMode & if runSelfTest then SelfTestMode) & if error then FailSafeMode & if powerOff then off
FUN31	System shall always satisfy patientSafe
FUN32	in FailSafeMode System shall always satisfy patientSafe
FUN33	if powerFailure System shall at the next timepoint satisfy patientSafe
FUN34	if gasSupplyFailure System shall at the next timepoint satisfy patientSafe
FUN37	if powerFailure System shall for 120 minutes satisfy !off
FUN38_1	if param_V > paramMax_V | param_V < paramMin_V System shall at the next timepoint satisfy paramAlarm_V
FUN39	before PSVMode | PCVMode System shall eventually satisfy enterAlarmThresholds
FUN40	if P_insp > MaxP_insp System shall at the next timepoint satisfy inspiratoryPhaseEnd & expirationPhaseStart
FUN41	if GUIFailue | !GUIConnected System shall at the next timepoint satisfy ventilating & highPriorityAlarm