Hazard Analysis

Define the purpose of the analysis: capture the notion of loss in the system and identify the related hazards.

Hazards

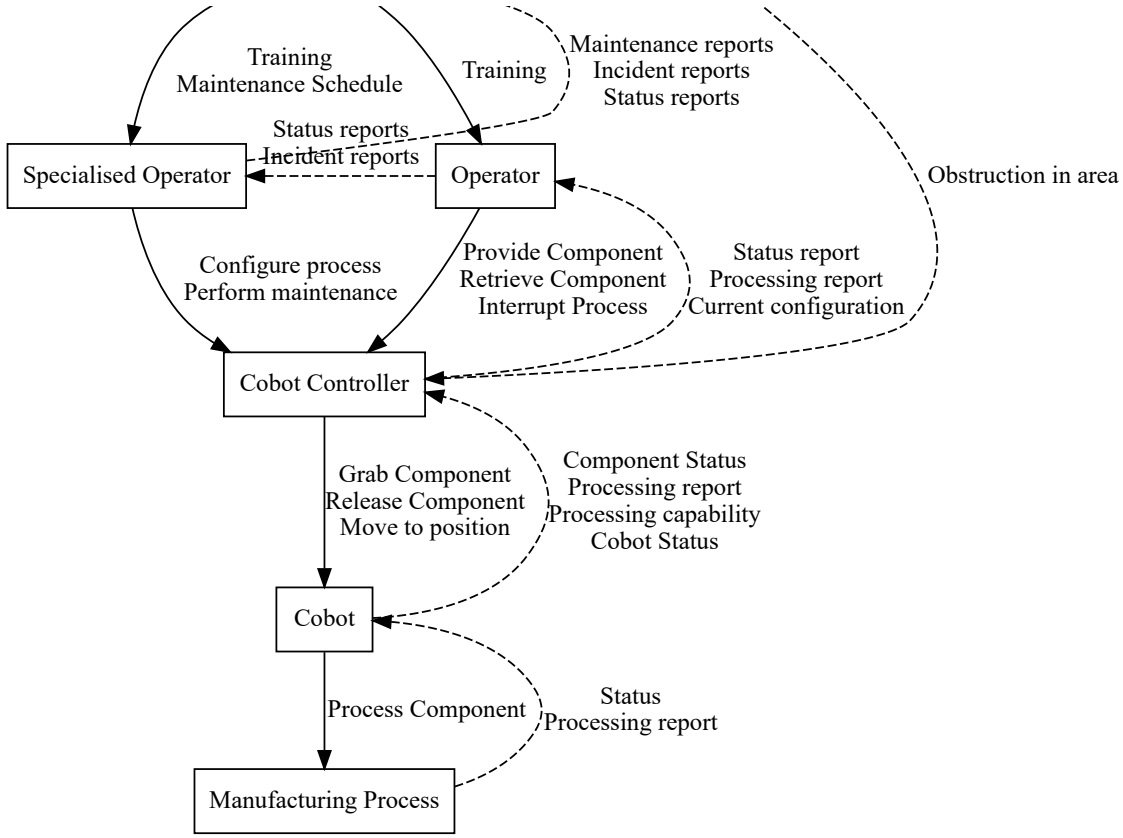
H1	Violation of minimum separation requirements between human, Cobot, and/or other equipment	[SC1, SC2]
H2	Individual or Objects enter dangerous area	[SC3, SC4]
H3	Equipment or Component subject to unnecessary stress	[SC5, SC6]
H4	Supplied component cannot be correctly processed	[SC7, SC8]
H5	Equipment operated outside safe conditions	[SC5]
H6	Component not secured during processing or transport	[SC9]
H7	Components do not move through the processing chain	[SC10]

Safety Constraints

SC1	Autonomous equipment should maintain minimum separation requirements
SC2	Personnel should maintain minimum separation requirements from live Equipment
SC3	Personnel should keep outside of the working areas
SC4	The working areas should be kept clear of obstructions
SC5	Equipment should be operated within safe operation parameters
SC6	Equipment should be regularly maintained and inspected
SC7	Only suitable components should be provided for processing
SC8	The Equipment configuration should support the required process
SC9	Components should be secured during transport, processing, and handover
SC10	Components should be processed and dispatched in a timely manner

Control Structure

Model the control structure to capture the relationships between the components in the system.



Components

Operations Management	Sets the operational objectives for the business and supports the operations.
Specialised Operator	Assures maintenance and configuration operations for the Cobot.
Operator	Interacts with the Cobot to perform the required processing for the component
Cobot Controller	Interfaces with the Operator to provide Components to the Automatic Tool.
Cobot	Secures component for transport and processing.
Manufacturing Process	Allows processing of Components.
Obstruction detector	Identifies the presence of obstruction in the working area

Control Actions

Action	Source	Target
Safety Standards		Operations Management
Cobot Operational Parameters		Operations Management
Training	Operations Management	Specialised Operator
Maintenance Schedule	Operations Management	Specialised Operator

Provide Component	Operator	Cobot Controller
Retrieve Component	Operator	Cobot Controller
Interrupt Process	Operator	Cobot Controller
Grab Component	Cobot Controller	Cobot
Release Component	Cobot Controller	Cobot
Move to position	Cobot Controller	Cobot
Process Component	Cobot	Manufacturing Process

Unsafe Control Actions

Identify the Control Actions which have the possibility to lead to a hazard

UCA1-D-1	Duration	Training	Training ends before Specialised Operator is fully familiarised with safety policies and/or
UCA1-N-1	Not Providing	Training	No training is delivered to the Specialised Operator working with a Cobot
UCA1-N-2	Not Providing	Training	Training is not re-assessed for the Specialised Operator when changes occurred in the Eq
UCA1-T-1	Scheduling	Training	Updated procedures are circulated after changes have taken place in the work areas
UCA2-N-1	Not Providing	Maintenance Schedule	The Maintenance Schedule is not provided when the Specialised Operator is in charge of
UCA3-D-1	Duration	Training	Training ends before Operator is fully familiarised with safety policies and/or the Equipm
UCA3-N-1	Not Providing	Training	The Operator is unaware of safe operational conditions when operating the Equipment
UCA3-T-1	Scheduling	Training	Updated procedures are circulated after changes have taken place in the work areas
UCA4-D-1	Duration	Provide Component	The Operator keeps holding on to a secured Component while the Cobot is moving to ar
UCA4-D-2	Duration	Provide Component	The Operator releases a Component before it is secured
UCA4-N-1	Not Providing	Provide Component	The Operator does not provide a Component when one is available and the Cobot is rea
UCA4-P-1	Providing	Provide Component	The Operator provides a Component when the controller has been configured for a diffe
UCA4-P-2	Providing	Provide Component	The Operator provides an unprepared or damaged Component
UCA4-P-3	Providing	Provide Component	The Operator provides a Component in the wrong position or orientation
UCA4-T-1	Scheduling	Provide Component	The Operator provides a Component to the Cobot while another is being processed
UCA4-T-2	Scheduling	Provide Component	The Operator provides a Component to the Cobot while it is approaching for the handov
UCA4-T-3	Scheduling	Provide Component	The Operator provides a Component when the controller has not been configured
UCA5-D-1	Duration	Retrieve Component	The Operator releases a Component before he has secured it
UCA5-N-1	Not Providing	Retrieve Component	The Operator does not collect the processed Component
UCA5-P-1	Providing	Retrieve Component	The Operator retrieves the Component while it is secured by the Cobot
UCA5-P-2	Providing	Retrieve Component	The Operator retrieves the Component while it is being processed.
UCA5-P-3	Providing	Retrieve Component	The Operator retrieves a Component before it has been processed

UCA6-N-1	Not Providing	Interrupt Process	The Operator fails to interrupt the process when safe operational conditions are not met
UCA6-P-1	Providing	Interrupt Process	The Operator interrupts the process when the Cobot is under maintenance
UCA6-P-2	Providing	Interrupt Process	The Operator interrupts the process when no operation is underway
UCA6-P-3	Providing	Interrupt Process	The Operator interrupts the process while safe operational conditions are met
UCA7-D-1	Duration	Grab Component	The Cobot does not hold the Component until it is secured
UCA7-N-1	Not Providing	Grab Component	The Cobot does not grab the Component provided by the Operator when it is in handov
UCA7-P-1	Providing	Grab Component	The Cobot grabs the Component while it has a high velocity
UCA7-P-2	Providing	Grab Component	The Cobot grabs a Component while the Effector is already in use
UCA7-P-3	Providing	Grab Component	The Cobot grabs a damaged or unprepared Component
UCA7-P-4	Providing	Grab Component	The Cobot grabs a component in the wrong orientation or position
UCA7-T-1	Scheduling	Grab Component	The Cobot grabs a component before it has been released by the Operator
UCA8-D-1	Duration	Release Component	The Cobot releases a Component too early during handover before it is secured
UCA8-N-1	Not Providing	Release Component	The Cobot does not releases the processed component when the operator is ready to re
UCA8-T-1	Scheduling	Release Component	The Cobot releases the component during processing
UCA8-T-2	Scheduling	Release Component	The Cobot releases the component before it is safe to handle
UCA9-N-1	Not Providing	Move to position	The Cobot does not reach the target position
UCA9-P-1	Providing	Move to position	The Cobot moves position while under maintenance
UCA9-P-2	Providing	Move to position	The Cobot moves position while its path is obstructed
UCA9-P-3	Providing	Move to position	The Cobot moves position while it has an unsecured part
UCA9-T-1	Scheduling	Move to position	The Cobot moves to processing position before it has grabbed a Component
UCA9-T-2	Scheduling	Move to position	The Cobot moves position while grabbing a Component
UCA10-D-1	Duration	Process Component	The Cobot stops processing the part before the process is complete
UCA10-D-2	Duration	Process Component	The Cobot keeps processing the Component after the end of the configured process
UCA10-D-3	Duration	Process Component	The Cobot processes the part beyond the processing requirements
UCA10-P-1	Providing	Process Component	The Cobot processes a Component that is damaged
UCA10-P-2	Providing	Process Component	The Cobot processes a Component when the configured process is incompatible
UCA10-P-3	Providing	Process Component	The Cobot starts the processing when no Component is currently held
UCA10-P-4	Providing	Process Component	The Cobot processes a Component when minimum separation requirements are not met
UCA10-P-5	Providing	Process Component	The Cobot processes a Component when personnel is present in the processing area
UCA10-P-6	Providing	Process Component	The Cobot processes a Component when the tool is busy
UCA10-P-7	Providing	Process Component	The Cobot processes a Component when the tool is under maintenance
UCA10-P-8	Providing	Process Component	The Cobot processes a Component while under maintenance
UCA10-P-9	Providing	Process Component	The Cobot processes a Component held in the wrong position or orientation
UCA10-T-1	Scheduling	Process Component	The Cobot processes a component before it has been configured
UCA10-T-2	Scheduling	Process Component	The Cobot processes a component after an incident occurred and before resolution

UCA11-P-1	Providing	Configure process	The operator configures the process when it is already configured
UCA11-T-1	Scheduling	Configure process	The Operator configures the process while a part is under processing
UCA12-D-1	Duration	Perform maintenance	The Operator does not complete the maintenance operation or return to the operating n
UCA12-N-1	Not Providing	Perform maintenance	The Operator does not perform maintenance when the Cobot signals an incident
UCA12-N-2	Not Providing	Perform maintenance	The Operator does not perform regular maintenance of the Cobot
UCA12-P-1	Providing	Perform maintenance	The Operator performs maintenance while the Cobot is processing a part
UCA12-P-2	Providing	Perform maintenance	The Operator performs maintenance while the Cobot is not set in the appropriate mode

Causal Factor Analysis

Capture the causal events which lead to an unsafe control action

HCF1-D-1-1	UCA1-D-1	There is no assessment of the Specialised Operator following the training
HCF1-D-1-2	UCA1-D-1	The training does not include information required to work safely
HCF1-D-1-3	UCA1-D-1	Not all training material is covered during the training
HCF1-N-1-1	UCA1-N-1	Training scheduled after the start of operations
HCF1-N-1-2	UCA1-N-1	The need for training has not been identified
HCF1-N-1-3	UCA1-N-1	No training is available for the Cobot
HCF1-N-2-1	UCA1-N-2	Changes in the Equipment operation have not been identified
HCF1-N-2-2	UCA1-N-2	The need for re-assessment has not been identified
HCF1-N-2-3	UCA1-N-2	Changes in the safety procedures have not been identified
HCF1-N-2-4	UCA1-N-2	No updated training material is available
HCF1-T-1-1	UCA1-T-1	Changes identified too late
HCF1-T-1-2	UCA1-T-1	No syncronisation between controllers, or poor planning
HCF1-T-1-3	UCA1-T-1	No approval required for the deployment of changes
HCF1-T-1-4	UCA1-T-1	Changes deployed without approval
HCF4-D-1-1	UCA4-D-1	The Operator does not recognise/acknowledge the Component is secured
HCF4-D-1-2	UCA4-D-1	The Component is stuck in the Operator's hand
HCF4-D-1-3	UCA4-D-1	The Operator does not recognise/acknowledge the Cobot is ready to move
HCF4-D-1-4	UCA4-D-1	The Operator intentionally holds on the Component
HCF4-D-2-1	UCA4-D-2	The Operator does not recognise/acknowledge the Component is not secured
HCF4-D-2-2	UCA4-D-2	The Operator intentionally releases the Component
HCF4-D-2-3	UCA4-D-2	The Operator does not know the Component should be secured before release
HCF4-D-2-4	UCA4-D-2	The Component cannot be secured

HCF4-N-1-3	UCA4-N-1	The Operator's station is left unsupervised
HCF4-N-1-4	UCA4-N-1	The Operator does not recognise/acknowledge the Cobot is ready
HCF4-P-1-1	UCA4-P-1	The Operator cannot assess the configured process for the Cobot
HCF4-P-1-2	UCA4-P-1	The Operator ignores the configured process for the Cobot
HCF4-P-1-3	UCA4-P-1	The Operator cannot assess the suitability of the Component
HCF4-P-1-4	UCA4-P-1	The Operator does not remove unsuitable Components following a configuration change
HCF4-P-1-5	UCA4-P-1	The Operator assumes the configured process is correct for the available Components
HCF4-P-1-6	UCA4-P-1	The Operator was not made aware of configuration changes
HCF4-T-1-1	UCA4-T-1	The Operator does not recognise/acknowledge a Component is being processed
HCF4-T-1-2	UCA4-T-1	The Operator does not know to wait for the end of processing
HCF4-T-1-3	UCA4-T-1	The Operator ignores the due process for handover
HCF4-T-2-1	UCA4-T-2	The Operator does not recognise/acknowledge the Cobot is moving
HCF4-T-2-2	UCA4-T-2	The Operator skips the waiting due to time pressures
HCF4-T-2-3	UCA4-T-2	The Operator does not know to wait for the Cobot to stop for handover
HCF4-T-3-1	UCA4-T-3	The Operator cannot assess the configured process for the Cobot
HCF4-T-3-2	UCA4-T-3	The Operator ignores the lack of configuration
HCF4-T-3-3	UCA4-T-3	The Operator does not know to wait for a configured process
HCF4-T-3-4	UCA4-T-3	The Operator assumes a process is still configured after a reset
HCF4-T-3-5	UCA4-T-3	The Operator is not aware the configuration has been removed
HCF5-D-1-1	UCA5-D-1	The Operator cannot secure the unwieldy component
HCF5-D-1-2	UCA5-D-1	The Operator intentionally drops the Component
HCF5-D-1-3	UCA5-D-1	The Operator does not recognise/acknowledge the Component is secured
HCF5-D-1-4	UCA5-D-1	The Operator cannot carry the heavy component
HCF5-D-1-5	UCA5-D-1	The Operator ignores the securing policies
HCF7-D-1-1	UCA7-D-1	The Cobot cannot secure the Component
HCF7-D-1-2	UCA7-D-1	The Cobot is not configured to secure the component
HCF7-D-1-3	UCA7-D-1	The Cobot does not recognise/acknowledge the Component is not secured
HCF7-D-1-4	UCA7-D-1	The Actuator fails to hold the component
HCF7-D-1-5	UCA7-D-1	The Cobot is configured to handle different Components
HCF7-D-1-6	UCA7-D-1	The Cobot receives a release order
HCF7-N-1-1	UCA7-N-1	The Cobot does not recognise/acknowledge the Component
HCF7-N-1-2	UCA7-N-1	The Cobot identifies the Component as invalid/damaged
HCF7-N-1-3	UCA7-N-1	The Cobot is incorrectly/not configured
HCF7-N-1-4	UCA7-N-1	The Component is out of reach
HCF7-N-1-5	UCA7-N-1	The Cobot does not have a suitable Effector

HCF7-P-1-2	UCA7-P-1	The Cobot Controller configuration has no requirement on maximum velocity
HCF7-P-1-3	UCA7-P-1	The Cobot reported velocity is incorrect
HCF7-P-1-4	UCA7-P-1	The Cobot velocity is not measured often enough relative to its acceleration
HCF7-P-1-5	UCA7-P-1	The Cobot controller configuration exceeds the authorised maximum velocity
HCF7-P-1-6	UCA7-P-1	The Cobot controller assumes it is not moving
HCF7-P-1-7	UCA7-P-1	The Cobot does not acknowledge stopping/slowing down commands
HCF7-P-1-8	UCA7-P-1	The Cobot controller did not slow down the Cobot enough
HCF7-P-1-9	UCA7-P-1	The Cobot reported velocity is stale
HCF7-P-2-1	UCA7-P-2	The Cobot Controller does not recognise/acknowledge the Effector is in use
HCF7-P-2-2	UCA7-P-2	The Effector does not signal it is in use
HCF7-P-2-3	UCA7-P-2	The Cobot Controller assumes the Effector is not in use
HCF7-P-2-4	UCA7-P-2	The held Component does not trigger the Effector's sensors
HCF7-P-2-5	UCA7-P-2	The Component is stuck in the Effector
HCF7-P-2-6	UCA7-P-2	The Cobot Controller is mis-configured
HCF8-D-1-1	UCA8-D-1	The Cobot cannot identify the Component is not secured
HCF8-D-1-2	UCA8-D-1	The Cobot does not acknowledge the Component as not secured
HCF8-D-1-3	UCA8-D-1	The Cobot configuration does not check a component is secured before full release
HCF8-N-1-1	UCA8-N-1	The Cobot Controller does not identify the Operator as ready
HCF8-N-1-2	UCA8-N-1	The Cobot Controller does not identify it is holding a Component
HCF8-N-1-3	UCA8-N-1	The Effector is faulty and cannot release the Component
HCF8-N-1-4	UCA8-N-1	The Cobot Controller assumes it is under a different mode
HCF8-N-1-5	UCA8-N-1	The Cobot is in the wrong mode
HCF8-N-1-6	UCA8-N-1	The Cobot configuration does not specify a release operation
HCF8-N-1-7	UCA8-N-1	The Cobot configuration release specification is incorrect
HCF8-T-1-1	UCA8-T-1	The Cobot controller does not acknowledge/identify it is processing
HCF8-T-1-2	UCA8-T-1	The Effector is faulty
HCF8-T-1-3	UCA8-T-1	The Cobot Controller configuration includes a release during processing
HCF8-T-1-4	UCA8-T-1	The Cobot controller does not identify its current state in the process
HCF8-T-1-5	UCA8-T-1	The Cobot Controller assumes it is in a different state
HCF8-T-1-6	UCA8-T-1	The forces generated by the process are too important for the Effector
HCF8-T-1-7	UCA8-T-1	The Component is stuck in the Automatic Tool
HCF9-N-1-1	UCA9-N-1	The Cobot stops because of an obstruction
HCF9-N-1-2	UCA9-N-1	The target position is out of reach
HCF9-N-1-3	UCA9-N-1	The Cobot is interrupted while moving
HCF9-N-1-4	UCA9-N-1	The Cobot does not identify its current position

HCF9-P-1-3	UCA9-P-1	Cobot does not identify operator
HCF9-P-2-1	UCA9-P-2	Cobot does not identify the obstruction
HCF9-P-2-2	UCA9-P-2	Cobot identifies obstruction as outside of path
HCF9-P-3-1	UCA9-P-3	The Cobot Controller cannot identify/does not acknowledge it is holding a Component
HCF9-P-3-2	UCA9-P-3	The Effector does not report a Component is held
HCF9-P-3-3	UCA9-P-3	The Component is stuck in the Effector
HCF9-P-3-4	UCA9-P-3	The Cobot Controller cannot identify/does not acknowledge the Component is not secured
HCF9-P-3-5	UCA9-P-3	The Cobot Controller is not configured to assess whether a Component is secured or not
HCF9-P-3-6	UCA9-P-3	The Cobot Controller test to check if a Component is secure is incorrect/incomplete
HCF9-P-3-7	UCA9-P-3	The Effector reported wrong values for the Component secure check
HCF9-P-3-8	UCA9-P-3	The Cobot Controller does not assess if a component is secured before moving
HCF9-T-1-1	UCA9-T-1	Cobot does not recognise part is missing
HCF9-T-1-2	UCA9-T-1	Effector reports part is held
HCF9-T-2-1	UCA9-T-2	Cobot does not identify part as not secured
HCF9-T-2-2	UCA9-T-2	Effector incorrectly reports part as secured
HCF9-T-2-3	UCA9-T-2	Cobot does not wait for part to be secured
HCF10-D-2-1	UCA10-D-2	The Cobot Controller cannot assess the process is complete
HCF10-D-2-2	UCA10-D-2	The Tool does not stop
HCF10-D-2-3	UCA10-D-2	The Cobot Controller does not check the end of the process
HCF10-D-2-4	UCA10-D-2	The Cobot Controller does not acknowledge the end of the process
HCF10-D-2-5	UCA10-D-2	The Cobot Controller does not stop the tool
HCF10-D-2-6	UCA10-D-2	The Cobot Controller fails
HCF10-D-3-1	UCA10-D-3	The Cobot configuration does not implement the required process
HCF10-P-1-1	UCA10-P-1	The Cobot cannot/does not acknowledge a Component is damaged
HCF10-P-1-2	UCA10-P-1	The Cobot configuration does not assess whether a Component is damaged
HCF10-P-1-3	UCA10-P-1	The damage cannot be assessed by the Cobot
HCF10-P-1-4	UCA10-P-1	The sensors report the wrong information for the damage assessment
HCF10-P-1-5	UCA10-P-1	The test in the Cobot configuration is incomplete/incorrect
HCF10-P-2-1	UCA10-P-2	The Cobot cannot assess the current component matches the process
HCF10-P-2-2	UCA10-P-2	The Cobot configuration does not check the current component matches the process
HCF10-P-2-3	UCA10-P-2	The Cobot cannot assess the automatic tool is compatible with the process
HCF10-P-3-1	UCA10-P-3	The Cobot cannot check/does not acknowledge a Component is held
HCF10-P-3-2	UCA10-P-3	The Effectors reports a component is held
HCF10-P-3-3	UCA10-P-3	The Cobot assumes a component is held
HCF10-P-3-4	UCA10-P-3	The Effector is Faulty

HCF10-P-4-4	UCA10-P-4	The obstruction's distance is misreported
HCF10-P-4-5	UCA10-P-4	The baseline for separation measurement is incorrect with regards to requirements
HCF10-P-4-6	UCA10-P-4	The metrics for the reported and baseline obstruction distances differ
HCF10-P-4-7	UCA10-P-4	The obstruction is outside the sensors' domain
HCF10-P-4-8	UCA10-P-4	The obstruction information is stale
HCF10-P-4-9	UCA10-P-4	The obstruction occurred before initialisation of the barriers
HCF10-P-4-10	UCA10-P-4	Sensor is inactive
HCF10-P-4-11	UCA10-P-4	Sensors installed incorrectly
HCF10-P-4-12	UCA10-P-4	Sensor's refresh rate is too low
HCF10-P-4-13	UCA10-P-4	Sensor is not powered on
HCF10-P-4-14	UCA10-P-4	Sensor is faulty
HCF10-P-4-15	UCA10-P-4	Sensor's domain does not cover the required space
HCF10-P-4-16	UCA10-P-4	The obstruction went around the barriers
HCF10-P-4-17	UCA10-P-4	The obstruction is too small for detection
HCF10-P-6-1	UCA10-P-6	The Cobot cannot identify the tool is busy
HCF10-P-6-2	UCA10-P-6	The Cobot does not acknowledge the tool is busy
HCF10-P-6-3	UCA10-P-6	The Cobot assumes the tool is available
HCF10-P-7-1	UCA10-P-7	The Cobot cannot identify the Tool is under maintenance
HCF10-P-7-2	UCA10-P-7	The Cobot does not acknowledge the Tool is under maintenance
HCF10-P-7-3	UCA10-P-7	The Cobot assumes the Tool is available
HCF10-P-8-1	UCA10-P-8	Cobot does not identify maintenance mode
HCF10-P-8-2	UCA10-P-8	Cobot not configured in maintenance mode
HCF10-P-8-3	UCA10-P-8	Cobot does not identify Operator
HCF10-T-1-1	UCA10-T-1	The Cobot uses a default configuration
HCF10-T-1-2	UCA10-T-1	The Cobot does not identify it has not been configured
HCF10-T-1-3	UCA10-T-1	The Cobot assumes a faulty configuration
HCF10-T-3-1	UCA10-T-3	The Cobot does not know its position and/or velocity
HCF10-T-3-2	UCA10-T-3	The Cobot Configuration does not include the required position and/or velocity
HCF10-T-3-3	UCA10-T-3	The Cobot does not check the Configuration for required position and/or velocity
HCF10-T-3-4	UCA10-T-3	The required position and/or velocity are out of reach
HCF10-T-3-5	UCA10-T-3	The Cobot Configuration cannot check the required position and/or velocity
HCF10-T-3-6	UCA10-T-3	The Cobot assumes its position and/or velocity as correct
HCF10-T-3-7	UCA10-T-3	The Cobot controller issues the Process command before the position and/or velocity are correct
HCF10-T-4-1	UCA10-T-4	The Cobot assumes the component is still secured
HCF10-T-4-2	UCA10-T-4	The Cobot does not identify the component as unsecured

HCF10-T-4-6	UCA10-T-4	The Effector is faulty
HCF10-T-4-7	UCA10-T-4	The Cobot cannot secure the Component in the Tool