```
##########################################################################

----------------------------  Handle_Sys_Exit  --------------------------------

  function Handle_Sys_Exit (returnStatus: int)
      -- NOT IMPLEMENTED
      ProcessFinish(returnStatus)
    endFunction

----------------------------  Handle_Sys_Join  --------------------------------
  function Handle_Sys_Join (processID: int) returns int
      -- Identify the child process, make sure that the PID that is passed
      -- in is the PID of a valid process (and that it is really a child of this process)
      -- If it is not than we return '-1' to the caller. Then we can call Wait ForZombie
      -- and return whatever it returns
      --print("Handle_Sys_Join invoked!\n")
      --print("processID = ")
      --printInt(processID)
      --print("\n")
      var
        i: int
        child: ptr to ProcessControlBlock
        parent: ptr to ProcessControlBlock
        childsExitStatus: int

      parent = currentThread.myProcess

      -- Identify the child Process.
      -- Run validation to ensure that we are grabbing the correct process
      for i = 0 to MAX_NUMBER_OF_PROCESSES-1
          child = &processManager.processTable[i]
          if child.pid == processID && child.parentsPid == parent.pid && child.status != FREE
              -- Wait for it to terminiate and get its exidCode when it returns
              childsExitStatus = processManager.WaitForZombie(child)
              return childsExitStatus
            endIf
        endFor

      return -1

    endFunction

----------------------------  Handle_Sys_Fork  --------------------------------
  function Handle_Sys_Fork () returns int
    -- Allocate and set up new Thread and ProcessControlBlock objects
    -- Make a copy of the address space
    -- Invoke Thread.Fork to start up the new processs thread
    -- return the childs pid
     var
        newPCB: ptr to ProcessControlBlock
        oldPCB: ptr to ProcessControlBlock
        newThread: ptr to Thread
        ignore: int
        i: int
        oldUserPC: int

      --print("Handle_Sys_Fork invoked! \n")
      -- Enable Interrupts
      ignore = SetInterruptsTo(DISABLED)
```

```
      -- Get new thread and PCB and initialize them
      newPCB = processManager.GetANewProcess()
      oldPCB = currentThread.myProcess
      newThread = threadManager.GetANewThread()
      -- Initialize PCB

      newPCB.parentsPid = oldPCB.pid
      -- Initialize thread
      newThread.name = currentThread.name
      newThread.status = newPCB.status
      newThread.myProcess = newPCB
      newPCB.myThread = newThread

      -- Grab the values in the user register and store a copy
      -- in the new Thread
      SaveUserRegs(&newThread.userRegs[0])

      -- Re-enable inturrupts
      ignore = SetInterruptsTo(ENABLED)

      --TODO: Must share OpenFiles with parent

      -- We then need to reset the system stack top and
      --ensure that no other threads will touch our user/new stack.
      newThread.stackTop = &(newThread.systemStack[SYSTEM_STACK_SIZE-1])

      -- Next we need to allocate the new frames for this address space
      frameManager.GetNewFrames(& newPCB.addrSpace, oldPCB.addrSpace.numberOfPages)

      -- Copy all the pages!
      for i = 0 to oldPCB.addrSpace.numberOfPages-1
          if oldPCB.addrSpace.IsWritable(i)
              newPCB.addrSpace.SetWritable(i)
          else
              newPCB.addrSpace.ClearWritable(i)
            endIf
          MemoryCopy( newPCB.addrSpace.ExtractFrameAddr(i),
                      oldPCB.addrSpace.ExtractFrameAddr(i),
                      PAGE_SIZE)
        endFor

      -- Get the User PC (That is buried in the system stack of the current Process)
      -- This value should point to the instruction following the syscall
      oldUserPC = GetOldUserPCFromSystemStack()

      --Fork a new thread and have it 'resume execution in user-land'
      newThread.Fork(ResumeChildAfterFork, oldUserPC)
      return newPCB.pid
    endFunction

-----------------------------  Handle_Sys_Yield  ---------------------------------
  function Handle_Sys_Yield ()
      -- NOT IMPLEMENTED
      -- Not really a need for a Yield syscall in any OS that has preemptive scheduling,
      -- but it can be used to make sure that the other processes are really running.
      currentThread.Yield()
      --print("Handle_Sys_Yield invoked! \n")
    endFunction

-----------------------------  ResumeChildAfterFork ------------------------

function ResumeChildAfterFork(initPC: int)
    -- This new thread should:
    --    * Initilize the user registers
    --    * Initilize the user and system stacks
    --    * Figure out whfere in the user's address space to reurn to
```

```
    --    * invoke BecomeUserThread and jump into the user-level processID

    var
      ignore: int
      initSystemStackTop: int
      initUserStackTop: int
    -- Begin by disabling interrupts
    ignore = SetInterruptsTo(DISABLED)

    -- set the page table registers to point to the process's page
    -- table and set the user registers
    currentThread.myProcess.addrSpace.SetToThisPageTable()
    RestoreUserRegs(&currentThread.userRegs[0])


    -- Any future interrupts will save the user regs to the thread
    currentThread.isUserThread = true

    -- Reset system stake top and invoke 'BecomeUserThread'
    initSystemStackTop = (& currentThread.systemStack[SYSTEM_STACK_SIZE-1]) asInteger
    initUserStackTop = currentThread.userRegs[14]
    BecomeUserThread(initUserStackTop, initPC, initSystemStackTop)
  endFunction


----------------------------  ProcessFinish  -------------------------

  function ProcessFinish (exitStatus: int)
      --
      -- This routine is called when a process is to be terminated.  It will
      -- free the resources held by this process and will terminate the
      -- current thread.
      --
      var
        proc: ptr to ProcessControlBlock
        ignore: int

      -- Save exitStatus
      currentThread.myProcess.exitStatus = exitStatus

      -- Disable Interrupts
      ignore = SetInterruptsTo(DISABLED)

      -- Disconnect the PCB from the Thread
      proc = currentThread.myProcess
      currentThread.myProcess = null
      proc.myThread = null
      currentThread.isUserThread = false

      -- Close any open files (FOR NEXT PROJECT)

      --Re-enable interrupts
      ignore = SetInterruptsTo(ENABLED)

      -- Return all frames to the Free Pool and turn process into ZOMBIE
      frameManager.ReturnAllFrames( &proc.addrSpace)
      processManager.TurnIntoZombie(proc)

      --Terminate thread (Parent will deal with the Zombie)
      ThreadFinish()
    endFunction


----------  ProcessManager . TurnIntoZombie  ----------

      method TurnIntoZombie (p: ptr to ProcessControlBlock)
```

```
          -- Passed a pointer to a process to turn it into a zombie (dead but not gone), so that
          -- its exitStatus may be retrieved if needed by its parent
          -- Steps:
          --   1. Lock the process manager (since we will be messing with other PCBs)
          --   2. Identify the processes who are zombies. These children are now no longer
          --      needed so for each zombie child, change its status to 'FREE' and add it back to
          --      the PCB free list. Signal 'aProcessBecameFree' since other threads may be
waiting for
          --      a free PCB.
          --   3. Identify p's parents (The parent may be terminiated, so they may not have one)
          --   4. If p's parent is 'ACTIVE' then the method must turn p into a zombie. Execute a
broadcast on
          --      the aProcessDied condition, because the parent of p may be waiting for p to
exit.
          --   5. Otherwise (our parent is a zombie or non-existent) we do not need to turn p
into a zombie, so just change p's
          --      status to 'FREE', add it to the PCB free list, and signal the
aProcessBecameFree condtion variable
          --   6. Unlock the process manager

          var
            i: int
            child: ptr to ProcessControlBlock
            parent:ptr to ProcessControlBlock

          -- 1.Lock the process Manager
          processManagerLock.Lock()

          -- 2. Identify zombies and Free them
          for i=0 to MAX_NUMBER_OF_PROCESSES-1
              child= &processTable[i]
              if child.parentsPid == p.pid && child.status == ZOMBIE
                  child.status = FREE
                  freeList.AddToEnd(child)
                  aProcessBecameFree.Signal(& processManagerLock)
                endIf
            endFor

          -- 3. Identify p's parents
          parent = null
          for i=0 to MAX_NUMBER_OF_PROCESSES-1
              if processTable[i].pid == p.parentsPid
                  parent = &processTable[i]
                endIf
            endFor

          -- 4.  If p's parents Active (turn to zombie)
          -- 5.  Otherwise our parents non-existent/not Active
          if parent && parent.status == ACTIVE
              p.status = ZOMBIE
              aProcessDied.Broadcast(&processManagerLock)
          else
              p.status = FREE
              freeList.AddToEnd(p)
              aProcessBecameFree.Signal(&processManagerLock)
            endIf

          --6. Unlock process manager
            processManagerLock.Unlock()
        endMethod
      ----------  ProcessManager . FreeProcess  ----------

      method WaitForZombie (proc: ptr to ProcessControlBlock) returns int
          -- The method waits for a process to turn into a zombie.
          -- The exit status is saved and ads the PCB back to the freelist
          -- The exit status is returned.
```

```
  var
    exitStatusToReturn: int
  -- 1. Lock the Process Manager
  processManagerLock.Lock()

  -- 2. Wait until the status of proc is ZOMBIE
  while proc.status != ZOMBIE
      aProcessDied.Wait(& processManagerLock)
    endWhile

  -- 3. Get procs exit status
  exitStatusToReturn = proc.exitStatus

  -- 4. Change Proc's status to FREE and Add the PCB back to the list. S
  -- signal the 'aProcessBecameFree' variable
  proc.status = FREE
  freeList.AddToEnd(proc)
  aProcessBecameFree.Signal(& processManagerLock)

  -- 5. Unlock the process manager
  processManagerLock.Unlock()

  -- 6. Return exitStatus
  return exitStatusToReturn

endMethod
```