FORMAL SPECIFICATIONS OF KVM/370 KERNEL AND TRUSTED PROCESSES

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INTRODUCTION

This document contains the formal specification of the kernel and trusted processes of the Kernelized VM operating system (KVM/378). The specification utilizes the specification language INA JO, a proprietary product of System Development Corporation. INA JO is described in TM-6021/000/80, January 1978. This document assumes familiarity with INA JO.

The specification is divided into two main parts. Chapter two contains the specification of the kernel, and is split into nineteen sections corresponding to the main areas of functionality of the kernel. For the most part, little or no explanation of the kernel specification is provided; a prose description of each kernel function is contained in "Preliminary Design of Security Kernel for KVM/378", TM-5855/200/80, October 1977. Chapter three contains the specifications of the trusted processes. Each of the five trusted process descriptions has two subsections. The first subsection for each trusted process contains a prose description of the process, detailing its function. The second subsection contains the INA JO specification of the process.
2.1: KVM Security Policy

This section describes the security policy implemented by KVM/378. A security level is defined as an ordered pair \((L,C)\), where \(L\) is one of (Unclassified, Confidential, Secret, TopSecret), and \(C\) is a (possibly empty) set of special access categories (e.g., Crypto, Atomic Energy). A function "Dominates" is defined which represents the concept 'greater than or equal to' as applied to security levels. The types of access which can be granted and the concept of an access history are defined. The access history is an answer to the question "has subject \(S\) ever had read or write access to object \(O\)?"

The security criterion for the system is defined in two parts. The first is the non-discretionary policy and requires that:

1. a subject's clearance must dominate the classification of any object to be read; and
2. a subject's security level must exactly equal that of any object to be written.

The second part consists of the discretionary need-to-know controls, implemented as access control lists which specify whether or not a given object is protected against a particular type of access, and which subjects may have the specified access to the object.
21 May 1978

2.1 KVM Security Policy

specification KVM-Security-Kernel

module TopLevel

iscrimination of Security Level and related Functions /

type HiarchyLv1 = (Unclassified, Confidential, Secret, TopSecret),
    SpecialProtectionCompartment,
    Categories = set of SpecialProtectionCompartment,
    Class = HiarchyLv1 >< Categories

constant LowLevel = L"H:HiarchyLv1(A"J:HiarchyLv1(H <= J)).1 /*Unclassified*/,
    HighLevel = L"H:HiarchyLv1(A"J:HiarchyLv1(H <= J)).1 /*TopSecret*/,
    SystemLow = (LowLevel, empty),
    SystemHigh = (HighLevel, S"C:SpecialProtectionCompartment (true) )

constant DOMINATES (dominator: Class, dominated: Class) =
    (dominator.1 > dominated.1 & dominator.2 >> dominated.2)
    MergeUp (A: Class, B: Class) ==
        (A.1 > B.1 => A.1 <= B.1), A.2 || B.2
    MergeDown (A: Class, B: Class) ==
        (A.1 < B.1 => A.1 <= B.1), A.2 && B.2

// subjects and objects //

type Object, Subject < Object, AccessType

constant None, ReadOnly, ReadWrite : AccessType
distinct (None, ReadOnly, ReadWrite)

variable GrantedAccess (Subject, Object): AccessType,
    SecurityLevel (Object): Class,
    Trusted (Subject): boolean

    access history //

variable ReadAccessObtained (Subject, Object),
    WriteAccessObtained (Subject, Object): boolean

// non-discretionary security //</

criterion A"S:Subject, O:Object (TRUSTED(S) I
    "Security Property" / /
        (ReadAccessObtained(S,O) =>
            Dominates(SecurityLevel(S), SecurityLevel(O)) )
    "x-Property" / /
        & (WriteAccessObtained(S,O) =>
            SecurityLevel(S) = SecurityLevel(O)) )

// Discretionary Need-to-Know Access Controls //</

type AccessList = structure of
    (Read = set of Subject,
     Write = set of Subject,
Protr = boolean,
Protw = boolean

variable DirectoryAccess(Subject, Object):AccessType,
ACL(Object): AccessList

criterion A\"S:Subject, O:Object

( Trusted(S) )

\/* read access protection */
( ReadAccessObtained(S, O) & ACL(O).Protr -> S <: (ACL(O).Read || ACL(O).Write) )

\/* write access protection */
& ( WriteAccessObtained(S, O) & ACL(O).Protw -> S <: ACL(O).Write )

\/* The input parameter "R" used in these specifications corresponds to the parameter "REQUESTER" in the informal specifications according to the following assertion, which holds for all Kernel calls
E1"R: KProcBlok (R<:ProcessList & R.Procname = Requestor) 

R is the KProcBlok uniquely defined by the above */
This section contains the machine-defined structures and data. The reader interested in more details about these machine-dependencies is referred to "IBM System/370 Principles of Operations", GA22-7000-5, International Business Machines Corporation, August 1976.

/* SYSTEM/370 MACHINE DEFINED STRUCTURES AND DATA */

/* Address Translation (OAT) Structures */
type Byte
  type PartOfBytes = T"L: list of Byte (C"L = PageSize*1024)
  type PageTableEntry = VPage « boolean
  type PTEList = list of PageTableEntry,
                  PageTable = T"P: PTEList (C"P = PagesPerSegment),
                  SegmentTableEntry = PageTable « boolean,
                    STEList = list of SegmentTableEntry
  type ProtectionKey,
      KeyInStorage = structure of
        (Key = ProtectionKey,
         NoFetch = boolean,
         Refer = boolean, Change = boolean)
  constant Key#: ProtectionKey

/* Addressing Technique */
type VPage = T"I: integer (0 <= I < 16*1024/PageSize),
           ByteOffset = T"I: integer (0 <= I < PageSize*1024),
           Address378 = VPage « ByteOffset
This section defines the parameters and data types controlling paging and address space manipulations.

```
/* paging system constants */

constant PageSize = 2 /*2K=256B*/. SegmentSize = 64 /*64K=65536B*/,
PagesPerSegment = SegmentSize/PageSize /*32*/,
PageTableEntrySize = 2 /*Halfword=2 bytes*/, PageTableHeaderSize = 8,
SegmentTableEntrySize = 4, SegmentTableHeaderSize = 8,
SwapTableEntrySize = 8, SwapTableHeaderSize = 8,
PageTableSize = PageTableHeaderSize + PagesPerSegment*PageTableEntrySize,
SwapTableSize = SwapTableHeaderSize + PagesPerSegment*SwapTableEntrySize,
RoundSegments(X: VPage) = (X + PagesPerSegment - 1)/PagesPerSegment

/* type definitions for virtual address structure */

type Lock = T"integer (I >= 0)
type Status = (NKCPData, Free, EmptyPage, ReadOnly, ReadWrite, IN, OUT)
type PageFrameName, PageSlotName, SlotAddress, AddressSpaceDesignator

constant PO: PageFrameName /*name" of an NKCP's page */


type PageFrame = structure of
  (Addr = VPage,
   Status = (NKCPData, Free, EmptyPage, ReadOnly, ReadWrite),
   /* the following fields are meaningful only if status ~~ Free */
   Owner = ProcessName, VirtualName = PageFrameName,
   TLOCK = boolean,
   Intransit = (IN, OUT, FREE),
   /* following meaningful only if status = ReadOnly or ReadWrite */
   RealKey = KeyInStorage,
   ILOCK = Lock, OLOCK = Lock, ULOCK = boolean,
   PageSlot = PageFrame, Contents = PageOfBytes),

PageSlot = structure of
  (Addr = SlotAddress,
   Status = T"(Free, EmptyPage, ReadOnly, ReadWrite),
   /* the following fields meaningful only if status ~~ Free */
   Owner = ProcessName, Sname = PageSlotName,
   /* following field meaningful only if status = ReadOnly or ReadWrite */
   Contents = PageOfBytes),

VirtualPageName = structure of
  (VName = VirtualMachineName,
   A = AddressSpaceDesignator,
   Vaddr = VPage),

VirtualPage = structure of
  (Status = T"(ReadOnly, ReadWrite, EmptyPage),
   /* following fields meaningful only if status = EmptyPage */
```
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Paging Parameters

VSlot = PageSlotName,
SavedKey = KeyInStorage, Refer = boolean, Change = boolean,
Contents = PageOfBytes,
Valid = boolean,
/* following meaningful only if Valid = true */
Raddr = VPPage /n real page frame, if any */
VaddrList = set of VirtualPageName

variable RealAddress(ASpace, VPage): PageTableEntry,
VirtPage(ASpace, VPage): VirtualPage

variable SharedSegmentList: set of PageTable,
RealPages: set of PageFrame,
RealSlots: set of PageSlot

Invariant A"P1,P2: PageFrame (P1<:RealPages & P2<:RealPages
  & ((P1.Addr = P2.Addr 1
        P1.Owner = P2.Owner & P1.VirtualName = P2.VirtualName
        (V<:P1.VirtAddr.VaddrList &
         V<:P2.VirtAddr.VaddrList))

  -> P1 = P2))
  & S1,S2: PageSlot (S1<:RealSlots & S2<:RealSlots
    & (S1.Addr = S2.Addr
      & S1.Status == Free & S2.Status == Free
      & S1.Owner = S2.Owner & S1.Sname = S2.Sname)

  -> S1 = S2)
This section defines several macros which are heavily utilized throughout the remainder of the kernel specification (all of Chapter two).

macro CheckVM(R: KProcBlok, V: VirtualMachineName) ==
  V = SYSTEM
  LET "K = U"K: KVMblock (K: KVMtable & K.VMname = V)
  & K.Owner = R.ProcName

macro CheckASpace(R: KProcBlok, V: VirtualMachineName, A: AddressSpaceDesignator) ==
  CheckVM(R, V)
  & LET "AS = (V = SYSTEM => R.AddressSpace
      <> AddressSpace(K, A) )
  & AS.Exists

define CheckVPage(S: ASpace, P: VPage) ==
  S.Exists & P < S.NumberOfPages

macro CheckMPage(R: KProcBlok, V: VirtualMachineName, A: AddressSpaceDesignator, P: VPage) ==
  CheckASpace(R, V, A) & CheckVPage(AS, P)

macro CheckFrame(R: KProcBlok, Pframe: PageFrameName) ==
  LET "PF = U"P:PageFrame (P.Owner = R.ProcName & P.VirtualName = Pframe)

macro CheckSlot(R: KProcBlok, Slot: PageSlotName) ==
  LET "PS = U"S:PageSlot (S.Owner = R.ProcName & S.SName = Slot)
This section describes virtual address spaces and the functions that create and destroy them.

```plaintext
/* Address Space Definitions */
type ASpace = structure of
  /* first two fields uniquely identify this ASpace */
  A = AddressSpaceDesignator, Owner = Subject,
  Exists = boolean,
  /* the following are meaningless if ~Exists */
  PurgeTLBNeeded = boolean,
  NumberOfPages = VPage,
  Addresses = T'S:STEList (C'S > 0 & C'S <= 16x1024/SegmentSize)

variable AddressSpace(KVMblock, AddressSpaceDesignator): ASpace

variable Spaces: set of ASpace

constant NullSpace(AS:AddressSpace): boolean ==
  A" S:SegmentTableEntry, P:PageTableEntry
  (S<AS -> ~S.2 | (P<AS.1 -> ~P.2) )
  & A"i:VPage (i < A.NumberOfPages -> VirtPage(AS,i).Status = EmptyPage)

Invariant A"S1, S2: ASpace, K:KVMblock, A:AddressSpaceDesignator, P: KProcBlok
(S1<Spaces & S2<Spaces
  & K<KVMTable & P<P:ProcessList
  -> S1.Exists & S2.Exists
  & (S1.Owner = S2.Owner & S1.A = S2.A -> S1 = S2)
  & (P.AddressSpace = S1 => S1.A = 0
  & S1.Owner = P.ProcessName
  <> AddressSpace(K.A) = S1
  -> S1.A = A & S1.Owner = K.VMname)
  & E"K1: KVMblock,
    P1: KProcBlok, A1: AddressSpaceDesignator
    (P1.AddressSpace = S1
    & AddressSpace(K1,A1) = S1))
```
transform CreateAddressSpace (VM: VirtualMachineName, 
   Size: VPage,
   A: AddressSpaceDesignator,
   R: KProcBlock)
   refcond R<:ProcessList & R.Proctype = NKCP 
   & VM <= SYSTEM & CheckVM(R, VM) 
   & ~AddressSpace(K,A).Exists 
   effect (AreaOK(R.ProcName, (SegmentTableHeaderSize + 
   RoundSegments(S.size) + 
   (SegmentTableEntrySize + PageTableSize + SwapTableSize))) 
   => ReturnCode(R,0) 
   & E"Space:AddressSpace(K,A) = S & 
   NullSpace(S) & S.NumberOfPages = Size 
   & N"Spaces = Spaces || S"(S) 
   & AdjustQuota(R.ProcName, 
   SegmentTableHeaderSize + 
   RoundSegments(S.size) + 
   (SegmentTableEntrySize + PageTableSize + SwapTableSize)) 
   <= ReturnCode(R,1) & N"Spaces = Spaces 
   & N"K = K & AdjustQuota(R.ProcName,0) )
transform Destroy AddressSpace(VM: VirtualMachineName, 
A: AddressSpaceDesignator, 
R: KP-ocBlk)

refcond R<:Proc::ssList & R.ProcType = NKCP
 & Check::space(R, VM, A)
 & Null::space(AS)

effect N"Spaces = Spaces <-> S"(AS) & ~N"AS.Exists
 & AdjustQuota(R.ProcName, -(SegmentTableHeaderSize +
 RoundSegments(Size)*
 (SegmentTableEntrySize+PageTableSize+SwapTableSize)))

2.6 Create/Destroy Process

This section describes KVII's definition of a process and the functions that create and destroy processes.

```
type ProcessName = Class,
  KProcBlok = structure of
    (ProcName = ProcessName,
     Proctype = (NKCP, TRUSTED, AUDITED),
     MessageQueue = list of MsgBlok,
     MessagePending = boolean, MessagePendingReceived = boolean,
     IOInterrupts = set of IOIntBlok, IOInterruptPending = boolean,
     ClockComInterruptPending = boolean,
     TrackingQuantum = boolean,
     QuantumEnded = boolean,
     CPUInterruptPending = boolean,
     RemainingQuantum = SignedDoubleword, CPUtimer = SignedDoubleword,
     IntvlTimer = integer, IntvlTimerInterruptPending = boolean,
     Internals = IntState,
     AddressSpace = ASpace)

variable ProcessList: set of KProcBlok
```
transform CreateProcess (ASize, CSize: VPage, Code: list of PageFrameName, Page0: PageFrameName, Process: ProcessName, R: KProcBlok)

refcond R.ProcName = INITIATOR &
ProcessCount < MaxProcessCount /* integer constant */
& CSize < ASize & CSize = C"Code"
& A"I: VPage ( I <= CSize -> E1"PF:PageFrame (PF.Owner = INITIATOR
& PF.VirtualName = (Code:Page0).((I+1) )
& E1"PF:PageFrame (PF.Owner = INITIATOR
& PF.VirtualName = (Code:Page0).((I+1)
& PF.Status = (I=0 -> EmptyPage
<-> ReadWrite)))

effect ( SlotTest(ASize-CSize) => ReturnCode(R,1)
& N"ProcessList = ProcessList & N"Spaces = Spaces
& A"PF:PageFrame (N"PF = PF)
<-> AreaOK(INITIATOR, (KProcBlokSize + ASpaceSize(ASize)) ) =>
ReturnCode(R,2)
& N"ProcessList = ProcessList & N"Spaces = Spaces
& A"PF:PageFrame (N"PF = PF)
<-> ReturnCode(R,0) & AdjustQuota(INITIATOR,KProcBlokSize
+ ASpaceSize(ASize))
& E"PF:KProcBlok, S:ASpace, PF:PageFrame (N"Spaces = Spaces + S"(S)
& S.NumberOfPages = ASize
& N"ProcessList = ProcessList II S"(P) & P.ProcName = Process
& P.Owner = INITIATOR & PF.VirtualName = Page0
& N"PF.Owner = Process
& N"PF.VirtualName = PF0 /* PageFrameName Constant */
& P.AddressSpace = S & NoInterruptsPending(P)
& S.PurgeTLBneeded
& A"I: VPage ( I<=CSize => RealAddress(S,1).2
& E"PF:PageFrame (PF.Owner = Initiator & PF.VirtualName = (Code:Page0).((I+1)
& PF.Addr = RealAddress(S,1).1 )
& (I > CSize & I < ASize ->
-RealAddress(S,1).2)))))
transform DestroyProcess(Process: ProcessName,
R: KProcBlok)

refcond R.ProcName = INITIATOR & R<:ProcessList
& A"D: IODEvice (GrantedAccess(P.ProcName, D.Address) = None)
& A"M: MiniDiskName (GrantedAccess(P.ProcName, M) = None)
& A"S: SharedSegmentName (GrantedAccess(P.ProcName, S) = None)
effect E"S: ASpace (S<:Spaces & P.AddressSpace = S
& ( A"I: VPage (I < S.NumberOfPages
& RealAddress(S,I).2 -> A"PF: PageFrame
(PF.Addr = RealAddress(S,I).1 ->
PF.Status = ReadOnly))
=> N"Spaces = Spaces ⊕ S"(S)
& N"ProcessList = ProcessList ⊕ S"(P)
& ReturnCode(R,0)
& AdjustQuote(INITIATOR, - (KProcBlokSize
+ASpaceSize(S.NumberOfPages)))))
<> ReturnCode(R,1) )
This section describes KVM's virtual machines and the functions that create and destroy them.

type VirtualMachineName, KVMblock - structure of (VirtualMachineName, Owner = ProcessName)

constant SYSTEM: VirtualMachineName
variable KVMTable: set of KVMblock
transform CreateVM(VM: VirtualMachineName, NCKPName: ProcessName, R: KProcBlok)

refcond R.ProcName = INITIATOR & El"P: KProcBlok (P<:ProcessList & P.ProcName = NCKPName & P.ProcType = NCKP)


transform DestroyVM (VM:VirtualMachineName, 
R: KProcBlock)

refcond LET "K = U"K: KVMblock (K<KVMtable & K.VMName = VM) 
& A"A:AddressSpaceDesignator (Nullspace(AddressSpace(K,A)))
& (R.ProcName = INITIATOR | R.ProcName = K.Owner)

effect N"KVMtable = KVMtable ~ S"(K)
2.8 Grant/Revoke Functions

This section describes real IO devices and shared (memory) segments, and defines the functions that grant and revoke access to them.

```plaintext
type HeadNumber = 'H': integer (H >= 0 & H <= 50),
                 CylinderNumber = 'C': integer (C >= 0 & C <= 10000),

type ObjectName = structure of
  KindOfObject = (SharedSegment, HorizontalMinidisk, VerticalMinidisk, WholeDevice),
  Pages = list of PageFrameName,
  Vol = RealVolumeId,
  Slice = HeadNumber,
  Start = CylinderNumber,
  Finis = CylinderNumber,
  Dev = DeviceAddress

constant NullDevice: DeviceAddress

type OwnedVolume = structure of
  (Name = RealVolumeId,
   Device = DeviceAddress)

variable OwnedList: set of OwnedVolume,
   DeviceList: set of RealDevice,
   SharedVolumeDevices: set of DeviceAddress

constant Devtype(UnitType): DeviceDescription

define DeviceExists(D: DeviceAddress) == LET"Dv = U"Dv: RealDevice
   (Dv.Addr = D & Dv<DeviceList),
   VolumeMounted(V: RealVolumeId) ==
   LET"VOL = U"VOL: OwnedVolume (VOL.Name = V & VOL<OwnedList)
   & VOL.Device == NoDevice
```
type Grant = structure of
  (Access = set of (ReadOnly, ReadWrite),
   Class = (DASD, Terminal, Tape, UnitRecord),
   Dedicate = boolean,
   /\ following meaningful only if Class = DASD,\n   Tracks meaningful only if Horizontal = true,
   Cyls only if Vertical = true
   Horizontal = boolean,
   Vertical = boolean,
   Tracks = set of HeadNumber >> Access,\n   Cyls = set of CylinderNumber >> Access)

constant NoAccess: Grant
transform GrantAccess(Object; ObjectName,
    Acc: (ReadOnly, ReadWrite),
    P;
    ::kProcBlock)

refcond TRUSTED(R.ProcName) & R;ProcessList & P;ProcessList
    & (Object.KindOfObject = SharedSegment =>
        R.ProcName = INITIATOR
        & C;Object.Pages = PagesPerSegment
        & A;PageFrame; PageFrameName = (PageFrame;Object.Pages
        -> CheckFrame(R, PageFrame)
        & PP.Status = (ReadOnly, ReadWrite))
    & Object.KindOfObject = HorizontalMinidisk =>
        VolumeMounted(Object;Vol)
        & Vol.Name = Object;Vol & Vol.Division = Horizontal
        & Slice >= 0
        & Slice < DeVtype(V.DeviceType).TracksPerCylinder
    & Object.KindOfObject = VerticalMinidisk =>
        VolumeMounted(Object;Vol)
        & Vol.Division = Vertical
        & Start >= 0 & Start <= Finis
        & Finis < DeVtype(Vol.DeviceType).NumCyl
    & Object.KindOfObject = WholeDevice =>
        DeviceExists(Object;Dev)
        & Object.Dev = SharedVolumeDevices

effect (Object.KindOfObject = SharedSegment => El;PT; PageTable
    (PT;<N;SharedSegmentList
    & A;: integer (1 > B & 1 <= PagesPerSegment
    -> CheckFrame(R, Object;Pages))
    & PT; = PP)
    & PT; = N;SharedSegmentList(P)
    & PT;Name = Object;Name)
    & Object.KindOfObject = WholeDevice =>
        LET "G = GrantedAccess(P.ProcName, Object;Dev)
        & N;G.Access = G.Access II S"(Acc)
        & N;G.Dedicate = true
        & N;G.Class = DeviceType(Object;Dev).Class
    & VolumeMounted(Object;Vol)
        & LET "G = GrantedAccess(P.ProcName, VOL.Device)
        & N;G.Access = G.Access II S"(Acc)
        & N;G.Class = DOSD & N;G.Dedicate
        & Object.KindOfObject = HorizontalMinidisk =>
            N;G.Horizontal & N;G.Vertical
            & N;G.Tracks = G.Tracks II S"(Object.Slice, Acc)
    & Object.KindOfObject = VerticalMinidisk =>
            N;G.Vertical & N;G.Horizontal
            & N;G.Cyls = G.Cyls II
        S"Z: Cylinder-Number => (ReadOnly, ReadWrite)
            (Z;1 = Start & Z;1 <= Finis & Z;2 = Acc))

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Grant/Revoke Functions

transform ReleaseDevice (Device, DeviceAddress, P, Ri, KProcBlock)

refcond R ProcType = Trusted
& GrantedAccess (P, ProcName, Device) = NoAccess

effect N*GrantedAccess (P, ProcName, Device) = NoAccess
This section defines the functions which place and remove virtual pages in virtual address spaces.

```
transform AttachPage(Pframe; PageFrameName,
   Addr; VirtualPageName
R; KProcBlock)

refcond CheckFrame(R, Pframe)
   & PF.TLOCK = 0 & PF.Status;S"(EmptyPage, ReadWrite)
   & (Ad.2 -> U"P: PageFrame (P.Addr = Ad.1).Status = ReadWrite)

effect N"Ad.1 = PF.Addr & N"Ad.2
   & N"PF.Status = ReadWrite & N"PF.TLOCK
   & N"PF.RealKey.Key = (VP.Status = EmptyPage => Key0
      => VP.SavedKey.Key)
   & N"PF.RealKey.NoFetch = (VP.SavedKey.NoFetch & VP.Status = EmptyPage)
   & (PF.VirtAddr.Valid = ~N"PF.RealKey.Refer & ~N"PF.RealKey.Change
      & ~N"VP.Change & ~N"VP.Refer)
   & N"VP.Status = ReadWrite
   & Ad.2 = N"A.PurgeTLBNeeded
   & PF.Status = EmptyPage = N"PF.Contents = 0
   & N"PF.VirtAddr = N"VP & N"VP.VaddrList = VP.VaddrList II S"(Addr)
   &N"VP.Valid
```
transform DetachPage(Addr; VirtualPageName, 
R; KProcBlok)

refcond CheckASpace(R, Addr, VName, Addr, A) 
& LET AO = RealAddress(A, Addr, VAddr) 
& AO.2

effect N"A.PurgeTLBneeded & ~N"AD.2 
& N"VP.VirtList = VP.VirtList + S"(Addr) 
& (N"VP.VirtList = empty -> ~N"VP.Valid)
This section describes the functions overseeing the movement of real pages between real memory and direct-access storage devices. The system protects against mis-seeks by associating a key with each record on a disk track. This key is an encrypted address of the record. After locating the record (via SEARCHID), the key is verified to be the particular one desired (via SEARCHKEY). The key is not visible to the user nor to untrusted control software.

EnqueueSwap is not described in the preliminary design documentation provided in TM-5655/281E/88. This function is a common routine used by SwapIn and SwapOut. It enters swap requests into the queue of outstanding IO requests.

type SearchType < CCUOpCode, SlotKey,  
  SwapCheck = SearchType => SlotKey => integer,  
  SwapBlock = structure of  
    (ReqType = (IN, OUT),  
     Active = boolean,  
     Frame = VPage,  
     Slot = SlotAddress,  
     Notify = ProcessName,  
     IO = RequestName,  
     Check = SwapCheck),  
  SwapReq = list of SwapBlock

cconstant Clear, Nochecks: SwapCheck, NullSwap: SwapBlock
  RecNum(SlotAddress), TrackAddress(SlotAddress): integer

variable SwapQueue; set of SwapReq

Invariant A"SR: SwapReq((SR<SwapQueue  
  -> A"B: SwapBlock (B<SR -> B.Slot.1 = SR.1.Slot.1))  
& A"T: SwapReq (T<SwapQueue  
  & T.1.Slot.1 = SR.1.Slot.1 -> T = SR))
transform EnqueueSwap(PF; PageFrame,
  Direction IN,OUT)
Slot: PageSlot,
Chk: SwapCheck,
Notify KProcBlok,
ID: RequestName)
refcond PF, ILOCK = 0 & PF, OLOCK = 0 & PF, ULOCK
& PF, Intransit<0"(Free,Direction)
effect (Direction = OUT -> SetSlot(PF,Slot))
& N"PF, Intransit = Direction
& E"SR: SwapReg B: SwapBlok (B<SR & SR< N"SwapQueue
& B: ReqType = Direction
& B: Frame = PF. Addr & B: Slot = Slot. Addr
& B: Check = Chk
& B: Notify = Notify. ProcName & B: ID = ID)

/* future SWAP Daemon effect
A" SR: SwapReq B: SwapBlok (SR< N"SwapQueue & B<SR
  => (B: ID == ID & B: Notify == Notify, ProcName) )
& (Direction = OUT => N: Slot. Contents = PF. Contents
  <= Direction = IN => N"PF. Contents = Slot. Contents)
& N"PF. Intransit = Free
& N"Notify, ID: InterruptPending
& E"I: ID IntBlok (I< N"Notify, ID: Interrupts & I: ID = ID)
& (Direction = OUT => N" Slot
  <= N"PF). Status = ReadWrite

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transform SwapOut(Pframe: PageFrameName, 
    ID: RequestName, 
    R: KProcBlock)

refcond R<:ProcessList & CheckFrame(R, Pframe) 
    & PF.Status<:S("ReadOnly, ReadWrite")

effect E*P:PageSlot (PS.Status = Free & EnqueueSwap(PF, OUT, PS, 
    (RecNum(PS.Addr) = 1 => (SearchHAEq, PS.Addr, 
    <-> (SearchKeyEQ, 0"PS1: PageSlot
    (PS1<:ReadSlots 
    & TrackAddr(PS1.Addr) = TrackAddr(PS. Addr) 
    & RecNum(PS1.Addr) = 
    RecNum(PS. Addr)-1).Key,
    R, ID)) )

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2.10 Swapping Functions

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transform SwapIn(Pframe; PageFrameName,
Slot: PageSlotName,
IO: RequestName,
R: KprocBlok) 

refcond R:\ProcessList & CheckFrame(R, Pframe) & CheckSlot(R, Slot) 
& PS.Status = ReadWrite & PF.Status<:\"(EmptyPage, ReadWrite) 

effect EnqueueSwap(PF, IN, PS,
(SearchKeyEQ, PS.Key, 8),
R, IO)
This section contains the single function `StatusPage`, which returns status information about a virtual page to the NKCP owning the page.

```
transform StatusPage(Vpage: VirtualPageName /* VMName + Page Number */ ,
R: KProcBlock)
refcond CheckMPage(R, VPage, VMName, VPage, A, VPage, Vaddr) & R: ProcessList
          & LET "VP = VirtPage(AS, VPage, Vaddr)
          & LET "Ad = RealAddress(AS, VPage, Vaddr)
          & Ad.2 -> LET "PF = U "PF: PageFrame (PF: RealPages & PF, Addr = Ad.1)
effect (AO.2 => N "VP, Change = (VP, Change | PF, Change)
          & N "VP, Refer = (VP, Refer | PF, Refer)
          & N "Status, ReadWrite = (PF, Status = ReadWrite)
          & N "Status, Present = true
          <> ~AO.2 => ~N "Status, Present & N "Status, ReadWrite = true
          & N "Status, Slot = VP, VSlot)
          & N "Status, Refer = N "VP, Refer & N "Status, Change = N "VP, Change
```
This section contains the kernel functions that read and write storage keys in virtual pages.

transform SetStorageKey(VM: VirtualMachineName, 
  Page: VPage, 
  Key: KeyInStorage, 
  R: KProcBlock)

refcond R.Proctype = NKCP & R:<:ProcessList & CheckPage(R, VM, 0, Page) & LET"VP" = VirtPage(A.S, Page) & LET"Ad" = RealAddress(A.S, Page) & VP.Status = ReadWrite

effect N"VP.SavedKey = Key & (Ad.2 => LET"PF = UPF: PageFrame (PF:<:RealPages & PageFrame.Addr = Ad.1) & N"PF.RealKey.NoFetch = Key.NoFetch & N"PF.RealKey.Key = Key.Key & ~N"PF.RealKey.Change & ~N"PF.RealKey.Refer & N"VP.Change = (VP.Change | PF.RealKey.Change) & N"VP.Refer = (VP.Refer | PF.RealKey.Refer) <> ~Ad.2 => N"VP.Change = VP.Change & N"VP.Refer = VP.Refer)
transform ReadStorageKey(VM; VirtualMachineName, Page: 0..8191, 
& KProcBlock, 
& Key; KeyInStorage /* output */)

ref cond R.Proctype = NKCP & R,<;ProcessList & CheckPage(R, VM, 0, Page) & LET"VP = VirtPage(AS,Page) & LET"Ad = RealAddress(AS, Page)

effect (Ad.2 => LET"PF = U"PF; PageFrame (PF:<;RealPages & PF.Addr = Ad.1) & N"Key.Key = PF; RealKey.Key 
& N"Key.NoFetch = PF; RealKey.NoFetch 
& N"Key.Change = (PF; RealKey.Change | VPChange) 
& N"Key.Refer = (PF; RealKey.Refer | VP.Refer) 
This section contains the kernel functions that manipulate user locks on page frames.

\[
\text{transform LockPage}(Pframe: \text{PageFrameName}, \ R: \text{KProcBlock})
\]

\[
\text{refcond CheckFrame}(R, Pframe) \land PF.\text{ILOCK} = 0 \land \neg PF.\text{ULOCK}
\]

\[
\text{effect } PF.\text{ULOCK} = \text{true}
\]
transform UnlockPage(Pframe, PageFrameName, R, KPrintBlock)
refcond CheckFrame(R, Pframe) & PF.ULOCK
effect NPF.ULOCK = false
This section contains the kernel functions which oversee the basic process scheduling provided by the kernel. ScheduleProcess is invoked only by the (semi-trusted) scheduler. The function schedules NKCPs and trusted processes. Once an NKCP is active, it may request the remaining scheduling operations. ReceiveInterrupts and DispatchVM are fairly clear; the former asks the kernel to provide the NKCP with an outstanding interrupt, if one exists. ReleaseCPU signals the termination of activity of the process, and allows the kernel to activate the next available process. ResumeProcess allows an NKCP to modify its activity status bits without relinquishing the CPU to another process. For example, if the NKCP decides to turn on monitoring, it may do so by performing the ResumeProcess kernel call with the appropriate parameters.

```plaintext
type InterruptMask = structure of
    (Intv1Timer = boolean,
    Message = boolean,
    ClockComp = boolean,
    CPUtimer = boolean,
    IO = boolean,
    Quantend = boolean)
```

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transform ResumeProcess(NewPSW: ProgramStatusWord,
            Cregs: RegisterSet,
            MON: MonitorClasses,
            R: KProcBlock)

pred cond R<<ProcessList

effect N"SYSTEM-Cregs = Cregs
    & N"SYSTEM-PSW = NewPSW
    & N"SYSTEM-Cregs =
        ( (K2, K64), R.AddressSpace.Addresses,
        -1, 0, 0, 0,
        (false, false, false, true,
        false, false, true, R.Cregs, true),
        0, MON,
        (false, false, false, false, 0), 0, 0, 0, 0,
        (true, true, false, false,
        false, true, false, 'false, false), 512)
    & N"VMA = (R.AddressSpace.Addresses, R.Cregs, true, NewPSW,
        WorkArea, 0, 0, 0, 0)

transform RECEIVEInterrupts(M: InterruptMask,
R: KProcBlock)

refcond R:PropcessList

effect (R.IntvlTimerInterruptPending & M.IntvlTimer
  => SimulateExternalInterrupt(R, X'80')
  <> R.MessagePending & M.Message & ~R.MessagePendingReceived
  => SimulateExternalInterrupt(R, X'1002')
  <> R.ClockCompInterruptPending & M.ClockComp
  => SimulateExternalInterrupt(R, X'1004')
  <> R.CPUTimerInterruptPending & M.CPUTimer
  => SimulateExternalInterrupt(R, X'1005')
  <> R.I0Interrupts == empty & M.I0
   => E1"B:IOintBlock (N"R.I0Interrupts = R.I0Interrupts == S"B)
       & SimulateIOInterrupt(R, B.ReqType, B.Id) )
  <> N"R = R)
transform ReleaseCPU(R; KProcBlock)
refcond P<ProcessList

effect N"R.Gregs = SYSTEM.Gregs
& N"R.MON = SYSTEM.MON
& N"R.IntvITimer = SYSTEM.TIMER
& N"R.CPUTimer = SYSTEM.CPUTimer
+ (R.TrackingQuantum => R.CPUTimer - R.RemainingQuantum)
& El"P; KProcBlock (P<ProcessList & N"Requester = P.ProcName
& ResumeProcess(P; P.ResumePau, P.Gregs, P.MON)
& N"SYSTEM-TIMER = P.IntvITimer
& N"SYSTEM-CPUTimer =
(P.TrackingQuantum => P.RemainingQuantum
 <-> P.CPUTimer)
)

& PurifySharedSystems
transform ScheduleProcess(P, R: KProcBlock)
refcond P:<\text{ProcessList} & R:<\text{ProcessList} & R.ProcName = \text{SCHEDULER}

\text{effect} N"\text{Requester} = P.ProcName & \text{ResumeProcess}(P, P.ResumePause, P.Gregg, P.MON) \\
& N"\text{SYSTEM-TIMER} = P.IntvlTimer \\
& N"\text{SYSTEM-CPUTimer} = (P.TrackingQuantum => P.RemainingQuantum} \\
& => P.CPUTimer)
transform DispatchVM(VirtualMachineName, VirtualMachineName, AddressSpaceDesignator, ProgramStatusWord, RegisterSet, FregSet, DATSpec, HalfMask, Frame, Shadow, ControlSet, CPAset0),

Time: integer,

R: KProcBlock)

refcond R<ProcList & R.ProcType = NKCP
& Time > 0 & Time < MaxTimeSilence, 300 < 256

effect N'SYSTEM-Cregs = Cregs & N'SYSTEM-Fregs = Fregs
& N'SYSTEM-TIMER = Time

/* R, T, IO, EXT, EC, M, P = 1, W = 0 */
& N'SYSTEM-Cregs = (DAT.1, DAT.2, / Page & Segment Size /* AddressSpace(K,A).Addresses, */ CR 1 */

-1, 0, 0, 0,

/* VMA Control = VMA Mask >> MICBlockAddress
(Furnished by Kernel) */
(VMA.1, VMA.2, VMA.3, VMA.4, VMA.5, VMA.6, false, VMA.7),
MON, 0,

/* PER control = EventMask, RegisterMask, PerStart, PerEnd */
(PER.1, PER.2, PER.3, PER.4, 0, 0,
(true, true, false, false, false, false, false, false, false, false))
S12)

/* RealSegmentTbl, VirtCregs, VIP, VirtPSW,
WorkArea, VTtimer, 0, 0, 0 */
& N'KERNEL-MICBLOCK = (AS.Addresses, VMA.8.real, VMA.9, NewPsw, Workarea,
(VMA.7 => 0
=> Page8Present(AS) => RealAddress(AS, 0) + 80
=> RealAddress(R.AddressSpace, VMblock, VMTIMER), 0, 0, 0)

& CheckASpace(R, VirtualName, A)
This section contains the kernel functions dealing with allocation and deallocation of page frames and page slots. In KVM a page frame is an area of real memory, and a page slot is an area on a direct-access storage device. A page is the contents of a page frame or a page slot.

```plaintext
transform FreePageFrame(PF: PageFrame)
refcond PF.Status = ReadWrite & PF.ULOCK & ~PF.TLOCK
& PF.ILOCK = 0 & PF.OLOCK = 0 & PF.Intransit = Free

effect N"PF.Status = FREE & N"PF.VirtList = empty
& ~N"PF.VirtAddr.Valid
& A"VPN: VirtualPageName( VPN<:PF.VirtAddr.VaddrList
-> CheckASpace(UP: KProcBlobk (P,ProcName = PF.Owner),
VPN,VName,
VPN,A)
& N"AS.PurgeTLBNeeded)
```
transform FreeSlot(Slot: PageSlot)
refcond Slot.Status <\#S"(Free, EmptyPage)"
effect N"Slot.Status = Free
2.15 Allocation Functions

 transform ReleaseSlot(Slot: PageSlot, R: KProcBlk)

 recond R:ProcessList & R.ProcName<"S"(SCHEDULER, INITIATOR)

 effect FreeSlot(Slot)
constant InsertSwap(L: list of SwapBlok, AFTER: SwapBlok, NEW: SwapBlok) ==
(L..1 = AFTER => L :. NEW
<> InsertSwap(L :.2, AFTER, NEW); L..1)
transform ChainPage10(SR: SwapReq,
New: SwapBlok,
Where: SwapBlok,
R: KProcBlok)

refcond R<:ProcessList & R.ProcName = SCHEDULER
& SR:<:SwapQueue & Where:<:SR & ~SR.Active
& New.Slot.1 = Where.Slot.1

effect N"SR = InsertSwap(SR, Where, New)
transform ReleasePage(Page: VirtualPageName, 
R: XProcBlock)

& LET "VP = VirtPage(AS, Page.Vaddr) & VP.Status == EmptyPage

effect N "VP.Status = EmptyPage 
& (VP.Valid => FreePageFrame(U"PF: PageFrame (PF.Addr = VP.Raddr) )  
<> FreeSlot(U"PS: PageSlot( PS.Sname = VP.VSlot & PS.Owner = R.ProcName) ) )
transform SetSlot(PF: PageFrame, Slot: PageSlot)

refcond PF.Status:<S"(ReadWrite, ReadOnly) & PF.InTransit == IN
& PF.ILOCK = 0 & PF.OLOCK = 0 & -PF.ULOCK
& FS.Status = Free

effect N"Slot.Status = EmptyPage
& N"Slot.Owner = PF.Owner & N"Slot.Sname = PF.VirtAddr.VaddrList.1
& N"PF.VirtAddr.VSlot = N"Slot.Sname
transform AssignSlot(PF: PageFrame,
    Slot: PageSlot,
    R: KProcBlok)

refcond R:\ProcessList & R.ProcName = SCHEDULER

effect SetSlot(PF, Slot)
transform StealPageFrame(PF: PageFrame, ID: RequestName, Notify, R: KProcBlock)
refcond R: ProcessList & R.ProcName = SCHEDULER
& PF.Status = ReadWrite & ~PF_UNIX & ~PF.TLOCK
& PF.ILOCK = 0 & PF.OLOCK = 0
& PF.Intransit = IN
effect FreePageFrame(PF)
& (PF.VirtAddr.Change ->
  EN: PageSlot(PS.Status = Free
        & EnqueueSwap(PF, OUT, PS, Notify, ID)))
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transform GetPageFrame(ID: RequestName,
R: KProcBlock,
PFrame: PageFrameName)

refcond R<ProcessList

effect N"Pframe = R.GetPageCount & N"R.GetPageCount = R.GetPageCount + 1
& (E"PF: PageFrame (PF.Status = Free) =>
E1"PF: PageFrame (N"PF.Owner = R.ProcName
& N"PF.VirtualName = N"Pframe
& N"PF.Status = EmptyPage)
& N"R.IOInterrupts = R.IOInterrupts || S"(ID)
& N"R.IOInterruptPending
=> E"PF: PageFrame (PF.Status = ReadWrite & ~PF.ULOCK & ~PF.TLOCK
& PF.LOCK = 0 & PF.OLOCK = 0)
=> StealPageFrame(PF, ID, R,
U"PI: KProcBlock (P.ProcName = SCHEDULER
& P<ProcessList))))
& (C"S"PF: PageFrame (PF.Status = Free) < MinFreePages
& E"PF: PageFrame (Stealable(PF)
=> E"PF:PageFrame(Stealable(PF) & StealPageFrame(PF, 0, 0,
U"PI: KProcBlock (P.ProcName = SCHEDULER
& P<ProcessList)))))
2.16: Spooling Functions

This section contains the kernel functions that support spooling using virtual spool cylinder addresses. All requests for spool-type IO are mapped from virtual to real addresses and, if necessary, delayed until the required real object becomes available.

type SlotNumber < integer,
    SpoolCylAddress = RealVolumeId << CylinderNumber,
    SpoolSlotAddress = SpoolCylAddress << SlotNumber,
    RealSpoolCyl = structure of
        (Exists = boolean,
         Addr = SpoolCylAddress,
         Status = (Free, EmptyPage, InUse))

variable RealCyl(SpoolCylAddress): RealSpoolCyl,
    RealSpoolCylinders: set of RealSpoolCyl
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2.16 Spooling Functions

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transform RequestSpoolIO(Direction: (IN,OUT),
Slot: Spool:SlotAddress,
ID: RequestName,
Page: VPage,
R: KProcBlock)

refcond R<:ProcessList & R.ProcType = NKCP
& CheckVPage(R.AddressSpace, Page)
& LET"RA = RealAddress(R.AddressSpace, Page)
& RA.2 & LET"PF = U"PF:PageFrame (PF.Addr = RA.1 & PF<:RealPages)
& PF.Intransit = Free
& (Direction = IN => PF.OLOCK = 0
& PF.Status<:S"(ReadWrite, EmptyPage)
& RealCyl(R, Slot.1).Exists
<=> PF.OLOCK = 0 & PF.Status = ReadWrite)

effect (RealCyl(R, Slot.1).Exists => N"RealCyl(R,Slot.1) = RealCyl(R,Slot.1)
<=> E"C: RealSpoolCylinder (Status(C) = Free
& C<:RealSpoolCylinders
& N"Status(C) = EmptyPage
& N"RealCyl(R, Slot.1).Addr = C.Addr
& N"RealCyl(R, Slot.1).Exists)
& E"SR: SwapReq, SB: SwapBlock (SR<:N"SwapQueue & SB<:SR
& SB.Frame = PF.Addr & SB.ReqType = Direction
& SB.Notify = R.ProcName & SB.ID = ID
& SB.Slot = (N"RealCyl(R, Slot.1), Slot.2)
& SW.Check = (RealSpoolCyl(R, Slot.1).Exists
<=> NoChecks
<=> Clear)

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2.16 Spooling Functions
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transform ReleaseSpoolCylinder(V; SpoolCylinderAddress, Ri: KProcBlock)


effect ¬N*:RealSpoolCyl(R, V).Exists
& ¬N*:SpoolStatus(RealSpoolCyl(R, V).Addr) = Free
This section contains the kernel functions that provide communication between processes. Trusted processes can both send and receive messages from all other processes. Semi-trusted processes can only receive messages. NKCPs can send messages to both semi-trusted and trusted processes, but can receive only from trusted processes.

```
type MessageId = structure of
    (MsgType = (OneWay, TwoWay, Reply),
     /* following meaningful only if MsgType = OneWay */
     Name = requestName,
     /* following meaningful only if MsgType = TwoWay */
     Time = UnsignedDoubleWord)

type MsgBlock = structure of
    (Sender = ProcessName,
     MessageId = MessageId,
     Contents = "L: list of Byte (C"L <= PageSize x 1024),
     MsgLength = T"I: integer (I >= 0 & I <= PageSize x 1024))
```
transform ReceiveMessage(Buffer: Address370, R: KProcBlock, 
MessageLength: ByteOffset, Sender: ProcessName, 
Id: MessageId)
refcond R.MessagePendingReceived & R.MessageQueue = nil 
& CheckVPage(R.AddressSpace, Buffer.1) 
& Buffer.2 + MessageLength <= PageSize * 1024 
& LET "Ad = RealAddress(R.AddressSpace, Buffer.1)
& Ad.2 
& LET "PF = VPFrame (PF<:RealPages & PF.Addr = Ad.1) 
& PF.Status = ReadWrite

effect ~N"R.MessagePendingReceived & N"R.MessageQueue = R.MessageQueue:2 
& N"Id = R.MessageQueue.1.MessageId 
& N"Sender = R.MessageQueue.1.Sender 
& N"MessageLength = R.MessageQueue.1.Length 
& A"i:ByteOffset (i < N"MessageLength -> 
N"PF.Contents.(i+Buffer.2) = R.MessageQueue.1.Contents.i) 
& N"R.MessagePending = (N"R.MessageQueue = nil)
transform Sendmessage(ID; MessageId, MessageLength: ByteOffset, Message: Address370, D, R: KProcBlok)

& CheckKPage(R.AddressSpace, Message.1) & Message.2 + MessageLength <= PageSize * 1024 & LET"Ad = RealAddress(R.AddressSpace, Message.1) & Ad.2 & LET"PF = U"PF: PageFrame (PF<>RealPages & PF.Addr = Ad.1)

effect (R.Id.MsgType = Reply & "E"B:ClockBlok

< ID.MsgType = Reply => E"B:ClockBlok (B<:ClockCompQueue & B.Proc = R.ProcName & B.Reason = MessageReq & B.Id = ID.Name & N"ClockCompQueue = ClockCompQueue 11 S"(B) ) )
transform ReadCPUId(ID: ProcessorId,
R: KProcBlok)

effect N"10 = SYSTEM-CPUId
This section contains the kernel functions that control and support three of the four timers provided by the S/370. Each NKCP is provided with its own set of virtual timers, which are mapped onto the real set when the NKCP is active. The three provided timers are the interval timer, the CPU timer, and the clock comparator. The latter is used for two purposes in KVM: the kernel uses it to time out two-way messages, and the NKCP may also use it for its own purposes. The kernel maintains a queue of requests to set the clock comparator. The fourth timer, the time-of-day clock, is read by a non-privileged instruction. KVM/370 provides no facility to write it during normal operation, but treats it as a read-only object.

constant Delta = 1000 /* Time in microseconds to handle a Kernel Call and redispach */
variable SETime: SignedDoubleword

type ClockBlok = structure of
    (Time = UnsignedDoubleWord,
     Proc = ProcessName,
     Reason = (ClockReq, MessageReq),
     /* following meaningful only if Reason = MessageReq */
     Id = RequestName)

variable ClockCompQueue: set of ClockBlok,
SystemClockCompId: ClockBlok
transform SetClockComparator (TIME: UnsignedDoubleword, 
R: KProcBlock)

effect E"B: ClockBlock (B<:"ClockCompQueue & B.Proc = Requester & B.Time = TIME & B.Reason = ClockReq & A"z: ClockBlock (z<:"ClockCompQueue & z.Proc = B.Proc & z.Reason = ClockReq => z = B)) & N"R.ClockCompInterruptPending = False & E1"x:<"ClockCompQueue (N"SYSTEMClockComparator = x.Time & N"SystemClockCompId = x) & A"y:<"ClockCompQueue (y.Time >= N"SYSTEMClockComparator)
transform ClockComparatorInterrupt() 
refcond SystemClockCompId<:ClockCompQueue 
& EL"P: KProcBloc (P<:ProcessList & P.Name = SystemClockCompId.Proc) 
& LET"B = U"ClockBloc (SystemClockCompId = B) 

/* Note: ClockComparatorInterrupt occurs when SYSTEM-ClockComparator < SYSTEM-TOODClock */ 
effect B.Reason = ClockReq => N"P.ClockComparatorInterruptPending 
& N"ClockCompQueue = ClockCompQueue = S"(B) 
<=> N"P.MessagePending = P.MessagePending ; B.Id 
& ( N"ClockCompQueue = nil => 
  N"SystemClockComparator = MaxClockCompValue 
<=> N"ClockCompQueue = nil => E"x<:N"ClockCompQueue 
(A"y<:N"ClockCompQueue (y.Time >= x.Time) 
& N"SystemClockComparator = x.Time 
& N"SystemClockCompId = X)) 

CLOCK COMPARATOR INVARIANTS: A"x:ClockBloc (x<:ClockCompQueue -> x.Time >= SYSTEMClockComparator) 
A"y,z:ClockBloc (y<:ClockCompQueue 
& z<:ClockCompQueue 
& z.Proc = y.Proc 
& z.Reason = ClockReq 
& y.Reason= ClockReq 
-> z = y) 
ClockCompQueue = nil -> SystemClockCompId<:ClockCompQueue 
& SystemClockCompId.Time = SYSTEMClockComparator
transform SetCPUTimer(Time: SignedDoubleword,  
R: KProcBlock)

refcond R.Proctype = NKCP

effect N"R.CPUTimer = Time
  & (Time < N"R.RemainingQuantum => N"R.TrackingQuantum = False
  & N"SETTime = Time
  => Time > N"R.RemainingQuantum => N"R.TrackingQuantum = True
  & N"SETTime = N"R.RemainingQuantum)
  & N"SYSTEM-CPUTimer <= N"SETTime
  & N"SYSTEM-CPUTimer >= N"SETTime - (Delta ♯ 4896)
  & N"R.CPUTimerInterruptPending = False
  & (R.TrackingQuantum => N"R.RemainingQuantum = SYSTEM-CPUTimer
  <=> R.TrackingQuantum => N"R.RemainingQuantum =
  R.RemainingQuantum-R.CPUTimer
transform ReadCPUTimer (R: KProcBlock, 
Time: SignedDoubleword /* output */ )

refcond R.Proctype = NKCP

effect (R.TrackingQuantum -> N"Time = R.CPUTimer -
R.RemainingQuantum +
SYSTEM-CPUTimer

<- R.TrackingQuantum -> N"Time = SYSTEM-CPUTimer)

CPU TIMER INVARIANTS: R.Proctype = NKCP -> (SYSTEM-CPUTimer <=
R.RemainingQuantum
& SYSTEM-CPUTimer <= R.CPUTimer
& R.TrackingQuantum <=
R.RemainingQuantum <= R.CPUTimer)
transform CPUPtimerInterrupt()
refcond R.Proctype = NKCP

 Мак CPU timer interrupt occurs when R.Proctype = NKCP
 & SYSTEM-CPUTimer < 8 "/

effect (R.TrackingQuantum => N"R.CPUTimer = R.CPUTimer -
 R.RemainingQuantum +
 SYSTEM-CPUTimer
 & N"R.RemainingQuantum = MaxCPUTimerValue
 & N"SETTime = N"R.CPUTimer
 & N"R.TrackingQuantum = False & N"R.QuantumEnded = True
 <=> R.TrackingQuantum => N"R.RemainingQuantum = R.RemainingQuantum
 - R.CPUTimer + SYSTEM-CPUTimer
 & N"R.CPUTimer = MaxCPUTimerValue
 & N"SETTime = N"R.RemainingQuantum
 & N"R.TrackingQuantum = True
 & N"R.CPUTimerInterruptPending = True)
 & N"SYSTEM-CPUTimer <= N"SETTime
 & N"SYSTEM-CPUTimer >=
 N"SETTime - (Delta * 4096)
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2.18 Timing Functions

transform SetIntervalTimer (Time: Integer,
R: KProcBlok)
refcond R.Proctype = NKCP
effect
N"SYSTEM-TIMER <= Time
& N"SYSTEM-TIMER >> Time - (Delta * 3 / 40)
transform ReadIntervalTimer(R: KProcBlock,
   Time: integer / output //)

refcond R.Proctype = NKCP

effect N'Time <= SYSTEM-TIMER
   & N'Time <= SYSTEM-TIMER + (Delta * 3 / 48)
transform IntervalTimerInterrupt()
refcond R.Proctype = NKCP & SYSTEM-TIMER < 0

/* An interval timer interrupt occurs when the machine timer update:
N"SYSTEM-TIMER = SYSTEM-TIMER - INTVL
causes
N"SYSTEM-TIMER < 0 & SYSTEM-TIMER >= 0 */
effect N"R.IntervalTimerInterruptPending = True
This section contains the kernel functions that perform real IO. Details of the functions' operation may be found in the preliminary design document of KYM/370, TM-5855/200/88.

type CCWAccessFlags = structure of
   Access = (Write, Read),
       TIC = boolean, DataTransfer = boolean, DataChaining = boolean,
       MultiTrack = boolean, Seek = boolean)

type IOintBlock = structure of
   (ID: RequestName,
    CSW: ChannelStatusWord)

type LockedBox, PreprocessedChannelProgram, SeekArg, IDA0,
   CCWCount = T"I: integer (0 <= I & I < 65536)

variable IORRequestCount: integer, LockedBoxList: set of LockedBox
constant LookCCW(PreprocessedChannelProgram, CCWCount): ChannelCommandWord,
   CheckTIC(PreprocessedChannelProgram, CCWCount, ByteOffset): boolean,
   LookIDA(PreprocessedChannelProgram, Address370, VPage): IDA0,
   IDACount(PreprocessedChannelProgram, CCWCount): VPage,
   LookSeek(PreprocessedChannelProgram, Address370, SeekArg)
variable IOFLAGS(DeviceAddress, CCWOpCode): CCWAccessFlags
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2.19 10 Functions

**TM-S062/101/00**

transform Request10(Device: DeviceAddress /* 0..4095 */ ,
ChannelProgram: PreprocessedChannelProgram /* includes CCWs, IDAW list, 
search and seek arguments */

VII: VirtualMachineName
ID: RequestName,
R: KProcBlok)

refcond LET "G = GrantedAccess (Device, Requester) & CheckASpace (R, VM, 0)
& A"i:integer (i > 0 & i <= ChannelProgram.NCCWs ->
LET "CCW = LookCCW(ChannelProgram, i)
& (i < ChannelProgram.NCCWs -> CCW.ChainCommand)
& LET "F = IOFlags(Device, CCW.Opcode)
& (F.Access = Write -> G.Access = ReadWrite)
& (F.TIC -> CCW.Addr < ChannelProgram.NCCWs
& i > 1 & Modif(CW) = nil
& ~LookCCW(ChannelProgram, i-1).DataChain
& CCW.Count = 1
& CheckTIC(ChannelProgram.CCW.Addr, 1))
& (F.DataTransfer =>
A"i:integer (ii<:CCW.DataChainExtensions
& ii > 0 ->
LET "CCWX = LookCCW(ChannelProgram, ii)
& CCWX.Opcode = CCW.Opcode
& CCWX.IndirectAccess)
& A"IDA<:CCW.IDAList
(LET "Ad = RealAddress(A, IDA.1)
& Ad.2
& LET "PF = U"PF:PageFrame
(PF.Addr = Ad.1
& PF:<RealPages)
& (F.Access = Write ->
PF.ILock = 0
& A"j:integer (j > 0
& j <= ChannelProgram.NCCWs ->
(i = j ! LET "CCW2 = LookCCW(ChannelProgram, j)
& (CCW2.Skip | IOFlags(Device, CCW2.Opcode).Access => Read
A"IDA2<:CCW2.IDAList (RealAddress(A, IDA2.1) =>
Ad.1 )) ))
< F.Access = Read =>
CCW.Skip | PF.QLock = 0
& A"k:integer

(k > 0 & k <= ChannelProgram.NCCWs ->
(i = k ! LET "CCW3 = LookCCW(ChannelProgram, k)
& IOFlags(Device, CCW3.Opcode).Access => Read =>
A"IDA3<:CCW3.IDALists (RealAddress(A, IDA3.1), 1 <= Ad.1)) )
< F.DataTransfer => <CCW.IndirectDataAccess)
& (CCW.ChainData -> F.DataChaining)
& F.MultiTrack -> <G.Horizontal
& (F.Control -> (CCW.Count = 1 & CCW.SL1))
& (G.Class = DASO =>
(F.Seek ->
(G.FullDisk => True

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<>G.Horizontal -> CCW.SeekAddr.Head <= G.Tracks
<>G.Vertical -> CCW.SeekAddress.Cyl <= G.Cyl()

& (i = 1 -> (CCW.Opcde = Seek & CCW.Opcde = SeekCylinder))
& (i = 2 -> (CCW.Opcde = SetFileMask
 & LET FM = CCW.FileMask
 & (G.Access = ReadOnly =>
   FM.PermitWrite = InhibitWrite
 & (G.Access = ReadOnly =>
   FM.PermitWrite = PermitAllWrite)
 & (G.Horizontal = FM.PermitSeek =
   InhibitAllSeek
 & (G.Vertical = FM.PermitSeek = PermitAllSeek
   & FM.PermitSeek = PermitCyl
   <> G.FullDisk = FM.PermitSeek = PermitAllSeek
   <> G.Dedicate = true)
   & FM.InhibitDiagWrite = true)))

<> True))))

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**10 Functions**

---

**effect**

\[ N'\text{IORequestCount} = \text{IORequestCount} + 1 \]

& E"LB: LockedBox \( N'\text{LockedBoxList} = \text{LockedBoxList} \oplus S'' \) (LB)

& LB.Nm = IORequestCount

& LB.IO = IO

& LB.NCCWes = ChannelProgram.NCCWes

& LB.Dev = Device & LB.Notify = R.ProcName

& A'"LBX<:\text{LockedBoxList} (LBX.Num < LB.Num)

& A"i:integer \( i > 0 \) & i <= ChannelProgram.NCCWes

-> LET"CCWA = LookCCW(ChannelProgram,i)

& LET"CCWN = (LB.ChannelProgram)

& LET"FF = IOFlags(Device,CCWA.Opcode)

& CCWN.Opcode = CCWA.Opcode & Modf(CCW.Opcode) = Modif (CCWA.)

& CCWN.Count = CCWA.Count

& CCWN.Addr = CCWA.Addr + LOC(LB)

& (F.DataTransfer => A"i:integer \( i > 0 \)

& j <= C"CCWA.IDAList

-> LET"WN = CCWN.IDAList.j

& LET"WA = CCWA.IDAList.j

& WN.2 = WA.2

& LET"AdN = RealAddress(A,Wa.1)

& WN.1 = AdN.1

& LET"PFN = P"PF:\text{PageFrame}(PF<:Real Pages

& PF.Addr = AcN.1)

& (F.Access = Write => N"PFN.OLOCK = PFN.OLOCK + 1

< F.Access = Read & ~CCWA.Skip =>

N"PFN.ILOCK = PFN.ILOCK + 1

& ~N"PFN.ULOCK & ~N"PFN.TLOCK))

<F.Seek => LookSeek(ChannelProgram,CCWA.Addr) =

LookSeek(LB.ChannelProgram,CCWN.Addr)

<=>F.Access & ~F.Seek => True))}
transform StartIO(LockedBoxId: integer, 
R: KProcBlock)

refcond R<:ProcessList & R.ProcName = SCHEDULER
& LET"L = LB: LockedBox(LB<:LockedBoxList & LB.Num = LockedBoxId)
& ~InProcess(L)
& A"B: LockedBox (B<:LockedBoxList & InProcess(B)
   -> B.Dev = L.Dev)

effect N"InProcess(L) & MachineDependent

/* Eventual IO Daemon effect:
 N"InProcess(L) & LET"P = U"B:KProcBlock (B.ProcName = L.Notify)
 & N"P.IOInterruptPending
 & E"B:IOintBlock (B<:N"P.IOInterrupts & B.IO = L.IO & B.Dev = L.Dev)
 & A"C: LBCCW (C<:L.ChanProg
   -> LET"F = I0Flags(L.Dev, C.OpCode)
   & (F.DataTransfer -> A"W: Address370
   (W<:C.IDAList -> LET"PF = U"P; PageFrame
   (P<:RealPages & P.Addr = W.1)
   & (F.Access = Write -> N"PF.OLOCK = PF.OLOCK - 1
   <- F.Access = Read -> N"PF.ILOCK = PF.ILOCK - 1
   <- true)))))
 & MachineDependent */
transform CancelIO(ID: RequestName, 
R: KProcBlock)

recond R:<ProcessList 
& E1"LB: LockedBox (LB:<LockedBoxList 
& LB.Notify = R.ProcName 
& LB.ID = ID)

effect E"LB: LockedBox (LB:<LockedBoxList 
& LB.Notify = R.ProcName 
& LB.ID = ID 
& N"LockedBoxList = LockedBoxList << S"(LB) 
& (InProcess(LB) -> MachineDependent) 
& N"InProcess(LB) 
& A"C: LBCCW (C:<LB. ChanProg -> 
LET"F = IOFlags(LB.Dev.C.OpCode) 
& F.DataTransfer -> A"H: Address376 (W:<C.IDAList -> LET"PF = U"PF:PageFrame 
(PF:<RealPages & PF.Addr = W.1) 
& (F.Access = Write => N"PF:OLOCK = PF:OLOCK -1 
<= F.Access = Read => N"PF:ILOCK = PF:ILOCK -1 
<= true)))))
transform WaitIODevice: DeviceAddress, ChannelProgram: PreprocessedChannelProgram, R: KProcBlock)

refcond R<:ProcessList & R.ProcName = NKCP
& LET"C = GrantedAccess(Device, R.ProcName)
& A"C:ChannelControlWord (C<:ChannelProgram.CCWs ->
LET"F = IOFlags(Device, C.Opcode)
& ¬F.TIC
& A"W: IOAW (W<:C.IOAWlist
-> LET"RA = RealAddress(R.AddressSpace, W.1)
& RA.2
& LET"PF = U"P:PageFrame (P<:RealPages
 & P.Addr = RA.2)
& (C.ChainData -> F.DataChaining)
& (F.MultiTrack -> ¬G.Horizontal)
& (F.Access = Write => PF.IOLock = 0
 & A"j:integer (j > 0
 & j < ChannelProgram.NCCWs
 -> LET"C2 = LookCCW(ChannelProgram, j)
 | A"W2:IOAW (W2<:C2.IOAWlist -> RealAddress(R.AddressSpace, W2.1).1 = RA.1))))
 & F.Access = Read => C.Skip |
PF.IOLock = 0
 & A"K:integer (K > 0 & K < ChannelProgram.NCCWs
 -> LET"C3 = LookCCW(ChannelProgram, K)
 | A"W3:IOAW (W3<:C3.IOAWords ->
 RealAddress(R.AddressSpace, W3.1).1 = RA.1))
 & true)
 & (F.DASD = G.FullDisk))

effect MachineDependent
This section contains the informal description of the Operator Process of KVM/370.

Overview

The Operator Process is linked to the operator's console at system initialization. The Operator Process thereafter accepts operator commands, and routes the command either to the affected NKCP, or to the trusted process which is to perform the actions dictated by the command. For the most part, the Operator Process merely routes the message, with little or no notice of the details of the command. The few commands requiring further processing are noted below. Necessarily, the Operator Process must know where the command is to be sent for processing. This often involves mapping a command operand such as a user id into an NKCP id. The Operator Process sends requests to the Authorization Process to perform such mappings. The VM operator commands have been separated by function into four categories: Miscellaneous, Spooling and File Control, Device Control, and Program Analysis and Monitor functions. These categories are described below.
## System Development Corporation

### 3.1.1 Operator Process (Informal)

#### TM-6062/101/00

#### KVM/370 Operator Commands

(see notes at end of table)

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<th>Command</th>
<th>S</th>
<th>Resp</th>
<th>Map</th>
<th>Destinations</th>
<th>Category</th>
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<td>not legal</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATTACH-RADDR</td>
<td>S Y</td>
<td>R-&gt;T</td>
<td>UProcess or AuthProcess</td>
<td>0,8</td>
<td></td>
</tr>
<tr>
<td>DETACH-CHANNEL</td>
<td>not legal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DETACH-RADDR</td>
<td>S Y</td>
<td>R-&gt;T</td>
<td>UProcess or AuthProcess</td>
<td>0,8</td>
<td></td>
</tr>
<tr>
<td>DISABLE</td>
<td>S Y</td>
<td>N</td>
<td>Network Process</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>DISCONN</td>
<td>not legal</td>
<td></td>
<td></td>
<td>0,8</td>
<td></td>
</tr>
<tr>
<td>ENABLE</td>
<td>S Y</td>
<td>N</td>
<td>Network Process</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>LOADBUF</td>
<td>S Y</td>
<td>N</td>
<td>UProcess</td>
<td>1,1</td>
<td></td>
</tr>
<tr>
<td>VARY</td>
<td>S Y</td>
<td>R-&gt;T</td>
<td>UProcess or AuthProcess</td>
<td>4,1</td>
<td></td>
</tr>
<tr>
<td>ACNT-USERIDS</td>
<td>Both Y</td>
<td>U-&gt;N</td>
<td>some NKCPs</td>
<td>7,2</td>
<td></td>
</tr>
<tr>
<td>ACNT-ALL</td>
<td>M Y</td>
<td>N</td>
<td>all NKCPs</td>
<td>2,2</td>
<td></td>
</tr>
<tr>
<td>DCP</td>
<td>S Y</td>
<td>N</td>
<td>NKCP</td>
<td>1,1</td>
<td></td>
</tr>
<tr>
<td>DMCP</td>
<td>S Y</td>
<td>N</td>
<td>NKCP</td>
<td>1,1</td>
<td></td>
</tr>
<tr>
<td>LOCATE-USERID</td>
<td>S Y</td>
<td>U-&gt;N</td>
<td>NKCP</td>
<td>3,1</td>
<td></td>
</tr>
<tr>
<td>LOCATE-RADDR</td>
<td>S Y</td>
<td>R-&gt;T</td>
<td>UProcess or AuthProcess</td>
<td>4,1</td>
<td></td>
</tr>
<tr>
<td>SAVESYS</td>
<td>not legal</td>
<td></td>
<td></td>
<td>0,8</td>
<td></td>
</tr>
<tr>
<td>STCP</td>
<td>S Y</td>
<td>N</td>
<td>NKCP</td>
<td>1,1</td>
<td></td>
</tr>
</tbody>
</table>
**Notes:**

The column headings are as follows:

- **Command** = command name
- **S/M** = single message versus multiple messages sent
- **Rasp Exp** = response expected (Y=yes, N=no)
- **Map** = mappings performed, if any
  - **U -> N** = user id to NKCP id
  - **R -> T** = real device address to device type
- **Destination** = to what processes the messages are sent
  - **AuthProcess** = Authorization Process
  - **URProcess** = Unit Record Process

**Category** = ordered pair of (input category, output category). The category refers to the classification of the command in the formal specification. Each operator command is separated into two equivalence classes by

- the processing required when the command is first received, and
- the processing required to compute one response from all the responses to messages sent in the processing of the original command.

1. **FORCE command responses** are provided by the Authorization Process as unsolicited messages rather than solicited responses because the number of expected responses is not known and because it simplifies the interaction.

2. A response is provided immediately -- no message response is needed.
OPERATOR COMMANDS:

MISCELLANEOUS

FUNCTIONS

AUTOLOG (A,B)

"Automatically log on and load a virtual machine with IPL defined in its directory."

[extend syntax to provide NKCP id (security level)]
reflect message to Authorization Process
print response

DIAL (Any)

"Logically attach a user terminal to a multi-access virtual system."
not allowed as an operator command in KVM/370

FORCE (A)

"Force the logoff of any virtual machine."

[extend syntax to provide "ALL" operand]
user id - map user id to NKCP id
reflect message to NKCP
no response expected
[response from Authorization Process]

ALL - reflect message to each NKCP
no response expected [separate responses from Authorization Process]

INDICATE (E)

"Display use of and contention for major system resources."

LOAD, QUEUES - reflect message to each NKCP
gather responses
compute "average" response
print computed response

I/O - reflect message to I/O Scheduler
print I/O Scheduler response
PAGING - reflect message to I/O Paging Scheduler
   print I/O Paging Scheduler response

USER - map user id to NKCP id
   reflect message to NKCP
   print NKCP response

LOGON (Any)
   "Gain access to a virtual system from a user terminal."
   not allowed as an operator command in KVM/370

LOGOFF (Any)
   "Terminate user activity on a virtual machine."
   reflect message to Authorization Process
   (response from Authorization Process)

HALT (A)
   "Stop any active channel program on a specified device."
   Kernel Call: HALT
   print Kernel response

LOCK (A)
   "Lock a user's pages in processor storage."
   user id - map user id to NKCP id
   reflect message to NKCP
   print NKCP response

SYSTEM - [extend syntax to provide NKCP id
   (security level)]
   reflect message to NKCP
   print NKCP response

MESSAGE (Any)
   "Send a specified message from one virtual machine to
   another."
   user id - map user id to NKCP id
   reflect message to NKCP
   no response to operator
3.1.1 Operator Process (Informal)

ALL - reflect message to each NKCP
no response to operator

MONITOR (A,E)
[Also listed under PROGRAM ANALYSIS AND MONITOR FUNCTIONS]

"Initiate or terminate the recording of events that occur in the real machine."

[extend syntax to provide NKCP id
(security level) / "ALL" operand]

NKCP id - reflect message to NKCP
print NKCP response

ALL - reflect message to NKCP
gather responses
print NKCP response

NETWORK (A,B,F)
[Also listed under DEVICE CONTROL FUNCTIONS]

"Provide loading, dumping, tracing, and other functions
for the 3704/3705 Communications Controller."

reflect message to Network Process
print Network Process response

QUERY

"Provide status information on the real or virtual machine, and miscellaneous CP functions."

PAGING - reflect message to I/O Paging Scheduler
print I/O Paging Scheduler response

PRIORITY - map user id to NKCP id
reflect message to NKCP
print NKCP response

SASSIST - [extend syntax to provide NKCP id
(security level) / "ALL" sub-operand]

NKCP id - reflect message to NKCP
print NKCP response

ALL - reflect message to each NKCP
gather responses
print amalgamated response
DATE, LINES, ORAF,
SYSTEM, NAMES, USERS, user id -
reflect message to Authorization Process
print Authorization Process response

UR - reflect message to URProcess
print URProcess response

ALL - reflect message to Authorization Process
and URProcess
Kernel Call: STORAGE
gather responses
print amalgamated response

TOSK - reflect message to each NKCP
gather responses
print amalgamated response

STORAGE - Kernel Call: STORAGE
print Kernel response

raddr - map raddr to device type
if device is unit record device:
reflect message to URProcess
print URProcess response
else:
reflect message to Authorization Process
print Authorization Process response

TAPES, FILES, READER, PRINTER, PUNCH, HOLD -
[extend syntax to provide NKCP id
(security level) / "ALL" operand]
reflect message to URProcess
print URProcess response

LOGMSG - print log message

DUMP - reflect message to Dump Processor
print Dump Processor response

SET (A,B,F)

"Establish system parameters for virtual and real
machines, as well as other VM/370 values."

FAVORED, RESERVE, PRIORITY -
map user id to NKCP id
reflect message to NKCP
print NKCP response
21 May 1978
System Development Corporation

3.1.1 Operator Process (Informal)  TM-6852/181/08

SASSIST - [extend syntax to provide NKCP id
   (security level) / "ALL" sub-operand]
   NKCP id - reflect message to NKCP
   print NKCP response
   ALL - reflect message to each NKCP
         gather responses
         print amalgamated response

LGGMSG - NULL - set log message to empty string
   nn - read next console line, and
        make it line nn in the current
        log message

DUMP - reflect message to Dump Processor
       (no response to operator)

RECORD, MODE - not allowed in KVM/370

SHUTDOWN (A)
"Terminate VM/370 activity in an orderly manner and
checkpoint the system."
Reflect message to Authorization Process, IAPProcess, and each NKCP
no response to operator

SLEEP (Any)
"Place the virtual machine in a dormant state, with the
keyboard locked."
Not allowed as an operator command in KVM/370

UNLOCK (A)
"Release previously locked page frames of real storage."
user id - map user id to NKCP id
   reflect message to NKCP
   print NKCP response
SYSTEM, VIRT - not allowed in KVM/370
WARNING (A.B)

"Transmit high priority messages or warnings to a user or all users."

user id - map user id to NKCP id
reflect message to NKCP
no response to operator

ALL - reflect message to each NKCP
no response to operator
OPERATOR COMMANDS:

SPOOLING
AND
FILE CONTROL
FUNCTIONS

All Spooling and File Control Commands are reflected to the Unit Record Process, which makes the necessary response. See the Unit Record Process Description for processing details.

BACKSPAC (D)
CHANGE (D)
DRAIN (D)
FLUSH (D)
FREE (D)
HOLD (D)
ORDER (D)
PURGE (D)
REPEAT (D)
SPACE (D)
START (D)
TRANSFER (D)
OPERATOR COMMANDS:
DEVICE CONTROL
FUNCTIONS

ATTACH (B)

"Attach a real device to a virtual machine or the real system."

CHANNEL - not allowed in KVM/370

raddr - map raddr to device type
if device type is unit record:
reflect message to URProcess
print URProcess response
else:
reflect message to Authorization Process
print Authorization Process response

DETACH (B)

"Remove a real or virtual device or channel from a virtual machine or the real system."

CHANNEL - not allowed in KVM/370

raddr - map raddr to device type
if device type is unit record:
reflect message to URProcess
print URProcess response
else:
reflect message to Authorization Process
print Authorization Process response

DISABLE (A,B)

"Disable direct or switched communication lines from the VM/370 system."

reflect message to Network Process
print Network Process response

DISCONN (Any)

"Disconnect the terminal from the user's virtual machine."

not allowed as an operator command in KVM/370
ENABLE (A.B)

"Connect specified communication lines to the system."
reflect message to Network Process
print Network Process response

LOADBUF (D)

"Load a specified train image into either the 1403 universal character set buffer or the 3211 universal character set or form control buffers."
reflect message to URProcess
print URProcess response

NETWORK
[See MISCELLANEOUS FUNCTIONS]

VARY (B)

"Allow or disallow the availability of a device to a virtual machine or the V71/370 control program."

map raddr to device type
if device type is unit record:
reflect message to URProcess
print URProcess response
else:
reflect message to Authorization Process
print Authorization Process response
ACNT (A)

"Render accounting information for and to the user."

user ids - map each user id to NKCP id
reflect message to each concerned NKCP
gather responses
print amalgamated response

ALL - reflect message to each NKCP
gather responses
print amalgamated response

DCP (C,E)

"Display real processor storage locations."

[extend syntax to provide NKCP id (security level)]
reflect message to NKCP
print NKCP response

DMCP (C,E)

"Dump the real storage locations to a user's virtual printer."

[extend syntax to provide NKCP id (security level)]
reflect message to NKCP
print NKCP response
LOCATE (C,E)

"Provide the starting location of the user's CP control blocks or (virtual or real) devices."

user id - map user id to NKCP id
    reflect message to NKCP
    print NKCP response

raddr - map raddr to device type
    if device type is unit record:
        reflect message to URProcess
        print URProcess response
    else:
        reflect message to Authorization Process
        print Authorization Process response

MONITOR
[See MISCELLANEOUS FUNCTIONS]

SAVESYS (E)

"Provide a storage copy of virtual machine storage, registers, and PSW contents as they currently exist."

not allowed as an operator command in KVM/378

STCP (C)

"Change the contents of real processor storage."
[extend syntax to provide NKCP id (security level)]

reflect message to NKCP
print NKCP response
Authorization Process
- Responses -

UserIdMapped
ResponseToOpRequest

NKCP Requests
OperatorMessage
QueryLogMsg
ResponseToOpRequest

Other Processes
- Responses -

ResponseToOpRequest

Other Processes
- Requests -

OperatorMessage
module OpProcess

type
DeviceTypes,
Char,
String = list of Char.

MessageLabel = (ResponseToOpRequest, OperatorRequest, MappedUserId, 
AdmNkcp, DtlNkcp, OpMsgPrinted, OpHitAttn, OpRequestRead),

KernelFunction = (GrantAccess, ReleaseDevice, CreateProcess, 
DestroyProcess, CreateAddressSpace, DestroyAddressSpace, 
RequestIO, ReceiveInterrupts, ReleaseCPU, ReceiveMessage),

ProcessName,
MessageId,
CommandName = (NIAL, LOGON, SET-RECORD, SET-MODE, SLEEP, 
UNLOCK-SYSTEM, UNLOCK-VIRT, ATTACH-CHANNEL, DETACH-CHANNEL, 
DISCONN, SAVESYS, 
AUTOLOG, INDICATE-ID, INDICATE-PAGING, 
LOGOFF, LOCK-SYSTEM, MONITOR-NKCP, NETWORK, QUERY-PAGING, 
QUERY-ASSIST-NKCP, QUERY-DASD, QUERY-TAPES, QUERY-LINES, 
QUERY-GRAPH, QUERY-SYSTEM, QUERY-NAMES, QUERY-USERS, QUERY-USERID, 
QUERY-UT, QUERY-DUMP, QUERY-FILES, QUERY-READER, QUERY-PRINTER, 
QUERY-PUNCH, QUERY-HOLD, SET-ASSIST-NKCP, SET-DUMP, 
UNLOCK-SYSTEM, BACKSPAC, CHANGE, DRAIN, FLUSH, FREE, HOLD, ORDER, 
PURGE, REPEAT, SPACE, START, TRANSFER, DISABLE, ENABLE, LOADBUF, 
DCP, DMCP, STCP, 
FORCE-ALL, INDICATE-LOAD, INDICATE-QUEUES, MESSAGE-ALL, 
MONITOR-ALL, QUERY-ASSIST-ALL, QUERY-TASK, SET-ASSIST-ALL, 
WARNING-ALL, ACNT-ALL, 
FORCE-USER1D, INDICATE-USER, LOCK-USERID, MESSAGE-USERID, 
QUERY-PRIORITY, SET-FAVORED, SET-RESERVED, SET-PRIORITY, 
UNLOCK-USERID, WARNING-USERID, LOCATE-USERID, 
QUERY-RADAR, ATTACH-RADAR, DETACH-RADAR, VARY, LOCATE-RADAR, 
HALT, QUERY-STORAGE, 
ACNT-USERIDS, QUERY-LOGMSG, SET-LOGMSG, QUERY-ALL, SHUTDOWN),

Cat0 = T"(NIAL, LOGON, SET-RECORD, SET-MODE, SLEEP, 
UNLOCK-SYSTEM, UNLOCK-VIRT, ATTACH-CHANNEL, DETACH-CHANNEL, 
DISCONN, SAVESYS),

Cat1 = T"(AUTOLOG, INDICATE-ID, INDICATE-PAGING, 
LOGOFF, LOCK-SYSTEM, MONITOR-NKCP, NETWORK, QUERY-PAGING, 
QUERY-ASSIST-NKCP, QUERY-DASD, QUERY-TAPES, QUERY-LINES, 
QUERY-GRAPH, QUERY-SYSTEM, QUERY-NAMES, QUERY-USERS, QUERY-USERID, 
QUERY-UT, QUERY-DUMP, QUERY-FILES, QUERY-READER, QUERY-PRINTER, 
QUERY-PUNCH, QUERY-HOLD, SET-ASSIST-NKCP, SET-DUMP, 
UNLOCK-SYSTEM, BACKSPAC, CHANGE, DRAIN, FLUSH, FREE, HOLD, ORDER, 
PURGE, REPEAT, SPACE, START, TRANSFER, DISABLE, ENABLE, LOADBUF, 
DCP, DMCP, STCP),

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System Development Corporation

3.1.2 Operator Process (Formal)
Cat2 = T"(FORCE-ALL,INDICATE-LOAD,INDICATE-QUEUES,MESSAGE-ALL, MONITOR-ALL,QUERY-SAASSIST-ALL,QUERY-TOSK,SET-SAASSIST-ALL, WARNING-ALL,ACNT-ALL),

Cat3 = T"(FORCE-USERID,INDICATE-USER,LOCK-USERID,MESSAGE-USERID, QUERY-PRIORITY,SET-FAVORED,SET-RESERVED,SET-PRIORITY, UNLOCK-USERID,WARNING-USERID,LOCATE-USERID),

Cat4 = T"(QUERY-RADDR,ATTACH-RADDR,DETACH-RADDR,VARY,LOCATE-RADDR),

Cat5 = T"(HALT,QUERY-Storage),

ConsoleOutputStatus = (Continuing,Idle),

ResponseStatus = (NoResponse,Responded),

RequestCategory = (OpFileRequest,ReadOpRequest,PrintOpMsg,MapUserId),

Answer = structure of(
  HMS = String,
  Text = String),

ResponseSlot = structure of(
  Respondent = ProcessName,
  Text = String,
  State = ResponseStatus),

PendingRequest = structure of(
  MsgId = MessageId,
  Kind = RequestCategory,
  Command = CommandName,
  Responses = set of ResponseSlot),

LogLine = structure of(
  Num = T"1":integer(1 <= I & I <= 99),
  Line = String)
variable:
Answer: list of Answer,
PendingRequests: set of PendingRequest,
LogMessage: set of LogLine,
CommandExpected: boolean,
ConsoleOutputState: ConsoleOutputStatus,
CurrentNkcps: set of ProcessName
initial
Answers = nil
&
PendingRequests = Empty
&
LogMessage = Empty
&
CommandExpected = true
&
ConsoleOutputState = Idle
&
CurrentRequests = Empty

invariant
A"P1,P2:PendingRequest (P1<:PendingRequests
&
P2<:PendingRequests ->
(P1.MsgId = P2.MsgId -> P1 = P2))
&
A"P:PendingRequest,R1,R2:ResponseSlot
(P<:PendingRequests&R1<:P.Responses&R2<:P.Responses ->
(R1.Respondent = R2.Respondent -> R1 = R2))
&
A"L1,L2:LogLine (L1<:LogMessage
&
L2<:LogMessage ->
(L1.Num = L2.Num -> L1 = L2))
constant
ProcessName,
10PagingScheduler, IOScheduler, NetworkProcess, DumpProcessor;
ProcessName,
TrustedProcesses = $"(OpProcess, URProcess, AuthProcess,
AcntProcess, UpdaterProcess),
MessageName(String): messageLabel,
Destination(CommandName): ProcessName,
DeviceType(DeviceAddress): DeviceTypes,
Raddr(String): DeviceAddress,
ClockRead: String,
ErrorMsg: String,
NewMsgId: MessageId,
SendMessage(ProcessName): KernelFunction,
KFunc(CommandName): KernelFunction,
DefinedElsewhere: boolean = true,
MakeString(set of LogLine): String,
LogPrompt: String,
Line/1(String): '1': integer(1 <= I & I <= 99),
Line(String): String

transform KernelCalled(K: KernelFunction)
effect (K = SendMessage -> DefinedElsewhere
  <> K = GrantAccess -> DefinedElsewhere
  <> K = ReleaseDevice -> DefinedElsewhere
  <> K = CreateProcess -> DefinedElsewhere
  <> K = DestroyProcess -> DefinedElsewhere
  <> K = CreateAddressSpace -> DefinedElsewhere
  <> K = DestroyAddressSpace -> DefinedElsewhere
  <> K = RequestIO -> DefinedElsewhere
  <> K = ReceiveInterrupts -> DefinedElsewhere
  <> K = ReleaseCPU -> DefinedElsewhere
  <> K = ReceiveMessage -> DefinedElsewhere
  <> true)
transform OpCat0(Command: CommandName)
refcond Command<:Cat0
effect N"Answers = Answers; (ClockRead, ErrorMsg)
& N"CommandExpected
21 May 1978
3.1.2 Operator Process (Formal)

System Development Corporation

transform OpCall(Command: CommandName)

refcond CommandExpected & Command<:Call

effect N"PendingRequests =
  (Command = SET-DUMP =>
   PendingRequests
   <> PendingRequests II S"((NewMsgId, OpRequest, Command, S"((Destination(Command), nil, NoResponse)))))

& N"CommandExpected &
& KernelCalled(SendMessage(Destination(Command)))
transform OpCat2(Command: CommandName)

refcond CommandExpected
& Command: Cat2

effect N"CommandExpected"
& A"P:ProcessName" (P:<CurrentNkcpps ->
KernelCalled(SendMessage(P)))
& (Command <<: S" (FORCE=ALL,WARN=ALL) ->
N"PendingRequests = PendingRequests")
S" (NewMsgId, OpRequest, Command,
S"R:ResponseSlot" E"P:ProcessName"
(P:<CurrentNkcpps
&
R = (P,nil, NoResponse))))
< N"PendingRequests = PendingRequests)
transform OpCat3(Command: CommandName, Nkcp: set of ProcessName)

refcond Command:<:Cat3

effect (Nkcp<-CurrentNkcp =>
  N"PendingRequests =
  (Command::<S" (FORCE=USERID, MESSAGE=USERID, WARNING=USERID) => PendingRequests
< > PendingRequests II
S" (NewMsgId, OpRequest, Command, S"R:ResponseSlot(E"P:ProcessName
(P<Nkcp
 &
R = (P,nil,NoResponse)))))
 &
N"CommandExpected
 &
A"P:ProcessName(P<Nkcp ->
KernelCalled(SendMessage(P))))
 &
NoError
< > Error
 &
N"PendingRequests = PendingRequests
 &
N"CommandExpected)
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3.1.2 Operator Process (Formal)

transform OpCat4(Command: CommandName, 
Raddr: DeviceAddress)

refcond CommandExpected 
& 
Command<:Cat4

effect N"PendingRequests = PendingRequests II 
S"((NewMsgId, 
OpRequest, 
Command, 
S"(((DeviceType(Raddr) = UnitRecord => 
URProcess 
<> AuthProcess), 
nil, 
NoResponse)))

& 
N"CommandExpected 
& 
(DeviceType(Raddr) = UnitRecord => 
KernelCalled(SendMessage(URProcess)) 
<> KernelCalled(SendMessage(AuthProcess)))
transform OpCat5(Command; CommandName)

recond CommandExpected
  & Command<:Cat5

effect KernelCalled(KFcn(Command))
  & N"Answers = Answer; (ClockRead,KernelResult)
  & N"CommandExpected
transform OpCat6(Command: CommandName)

refcond CommandExpected &
   Command:<Cat3 || S"(ACNT+USERIDS)

effect N"PendingRequests = PendingRequests ||
   S"(NewldId, MessageId, Command, 
   S"((AuthProcess,nil,NoResponse)))
   &
   N"CommandExpected &
   KernelCalled(SendMessage(AuthProcess))
transform OpCat7(Command: CommandName, Nkcps: set of ProcessName)

refcond Command = ACNT-USERIDS

effect (Nkcps<<CurrentNkcps >>
    N"PendingRequests = PendingRequests II
    S"((NewMsgid, OpRequest, Command,
        S"ResponseSlot(E"P:ProcessName
        (P:Nkcps
        &
        R = (P,nil,NoResponse)))))
    &
    N"CommandExpected
    &
    A"P:ProcessName(P<<Nkcps -> KernelCalled(SendMessage(P)))
    &
    NoError

<> Error
    &
    N"PendingRequests = PendingRequests
    &
    N"CommandExpected)
transform OpCat&n(Command: CommandName)

refcond CommandExpected
  & Command = QUERY-LOGMSG

effect N"Answers = Answers\(\) \(\)ClockRead\, MakeString\(\)\) LogMessage\)
  & N"CommandExpected
transform OpCat8b(Command: CommandName)

refcond CommandExpected

& Command = SET-LOGMSG

effect N"Answers = Answers: ,(ClockRead,LogPrompt)

& N"CommandExpected = false
transform OpCat&c(Line#: T$): integer(1 <= 1 & 1 <= 99),
   Line: String)

refcond ~CommandExpected

effect N"CommandExpected
   &
   (E"L:LogLine(L:LogMessage &
      L:Num = Line#) =>
      E"L:LogLine(L:LogMessage &
      L:Num = Line# &
      N"LogMessage = LogMessage => S"(L) ||
      S"((Line#.Line)))
   => N"LogMessage = LogMessage || S"((Line#.Line)))
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3.1.2 Operator Process (Formal)

\[
\text{transform (OpCat9(Command; CommandName))}
\]

\[
\text{refcond CommandExpected}
\]

\[
\text{Command = QUERY-ALL}
\]

\[
\text{effect N"CommandExpected}
\]

\[
\text{& N"PendingRequests = PendingRequests II}
\]

\[
\text{S"((NoMsgId, Command,}
\]

\[
\text{S"((Kernel, KernelResult, Responded),}
\]

\[
\text{(AuthProcess, nil, NoResponse),}
\]

\[
\text{(URProcess, nil, NoResponse))})}
\]

\[
\text{& KernelCalled(KFcn (QUERY-STORAGE))}
\]

\[
\text{& KernelCalled(SendMessage(AuthProcess))}
\]

\[
\text{& KernelCalled(SendMessage(URProcess))}
\]
transform OpCat10(Command: CommandName)

refcond CommandExpected

& Command = SHUTDOWN

effect N"CommandExpected

& KernelCalled(KFn(SHUTDOWN))

& KernelCalled(SendMessage(AuthProcess))

& KernelCalled(SendMessage(URProcess))

& KernelCalled(SendMessage(AccountProcess))

& A"P:ProcessName(P:<CurrentNkps ->

   KernelCalled(SendMessage(P)))
transform AUTH1(Nkcp; ProcessName)

effect (Nkcp<CurrentNkcp =>
Error
&
N"CurrentNkcp = CurrentNkcp
<> NoError
&
N"CurrentNkcp = CurrentNkcp II S"(Nkcp))
transform AUTH2(Nkcp: ProcessName)
effect (Nkcp<:CurrentNkcps =>
  NoError
  &
  N"CurrentNkcps = CurrentNkcps " S"(Nkcp)
  <>
  Error
  &
  N"CurrentNkcps = CurrentNkcps")
transform ProcessedResponse(P: PendingRequest, Text: String, Source: ProcessName)

refcond P<:PendingRequests & P.Kind = OpRequest &
     MsgName(Text) = ResponseToOpRequest

effect (E"R:ResponseSlot(R<:P.Responses &
              R.Respondent = Source &
              R.State = NoResponse) =>
           E"R:ResponseSlot(R<:P.Responses &
              R.Respondent = Source &
              R.State = NoResponse &
              (E"R1:ResponseSlot(R<:P.Responses &
                R1 = R &
                R1.State = NoResponse) =>
               N"Answers = Answers &
               N"PendingRequests = PendingRequests ∼ S"(P) II
               S"(P, MsgId, P.Kind, P.Command, P.Responses ∼ S"(R) II
               S"(R, Respondent, Response(Text), Responded)))
               => N"PendingRequests = PendingRequests ∼ S"(P)
               &
               N"Answers = Answers ∼ OpResponse(P)))
               => Error)

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3.1.2 Operator Process (Formal)
transform ProcessedCommand(Text: String)
effect (CommandExpected =>
  E"Command:CommandName(Command = CommandName(Text)) &
  (Command:<Cat0 =>
    OpCat0(Command)
  ) &
  Command:<Cat1 =>
    OpCat1(Command)
  ) &
  Command:<Cat2 =>
    OpCat2(Command)
  ) &
  Command:<Cat3 =>
    OpCat3(Command)
  ) &
  Command:<Cat4 =>
    OpCat4(Command, Raddr(Tr.text))
  ) &
  Command:<Cat5 =>
    OpCat5(Command)
  ) &
  Command = ACNT-USERIOS =>
    OpCat6(Command)
  ) &
  Command = QUERY-LOGMSG =>
    OpCat7a(Command)
  ) &
  Command = SET-LOGMSG =>
    OpCat7b(Command)
  ) &
  Command = QUERY-ALL =>
    OpCat9(Command)
  ) &
  Command = SHUTDOWN =>
    OpCat10(Command)
  ) &
  Error))
  ) &
  OpCat8c(Line#(Text), Line(Text))
transform MsgNkcp(MsgId: MessageId,  
Text: String,  
Source: ProcessName)

refcond Source =<: TrustedProcesses !  
S"(IODFCIagScheduter, ICSceduler,  
NetworkProcess, DumpProcessor)

effect (E"P: PendingRequest (P<: PendingRequests &  
P.MsgId = MsgId) =>  
E"P: PendingRequest (P<: PendingRequests &  
P.MsgId = MsgId  
&  
(P.Kind = OpRequest  
&  
MsgName(Text) = ResponseToOpRequest =>  
ProcessedResponse(P, Text, Source)  
< Error))  
< (MsgName(Text) = OperatorRequest =>  
N"Answers = Answers, (ClockRead, Text)  
< Error))}
transform MsgUR(MsgId: MessageId, 
  Text: String, 
  Source: ProcessName) 

refcond Source = URProcess 

effect (E^P:PendingRequest(P<:PendingRequests & 
  P.MsgId = MsgId) => 
  E^P:PendingRequest(P<:PendingRequests & 
  P.MsgId = MsgId 
  & 
  (P.Kind = OpRequest 
  & 
  MsgName(Text) = ResponseToOpRequest => 
  ProcessedResponse(P, Text, Source) 
  <> Error)) 
<> (MsgName(Text) = OperatorRequest => 
  N"Answers = Answers:. (ClockRead, Text) 
  <> Error))
transform Msg@OPS(MsgId: Message Id,
   Text: String,
   Source: ProcessName)

refcond Source = IOPagingScheduler

effect (E"P:PendingRequest(P<:PendingRequests &
   P.MsgId = MsgId) =>
   E"P:PendingRequest(P<:PendingRequests &
   P.MsgId = MsgId &
   (P.Kind = OpRequest &
   MsgName(Text) = ResponseToOpRequest =>
   ProcessedResponse(P, Text, Source)
   <> Error))
   <> (MsgName(Text) = OperatorRequest =>
   "N"Answer = Answers; (ClockRead, Text)
   <> Error))
transform MsgIOS(MsgId: MessageId,
Text: String,
Source: ProcessName)

refcond Source = IOScheduler

effect (E[P:PendingRequest(PS:PendingRequests &
P.MsgId = MsgId) =>
E[P:PendingRequest(PS:PendingRequests &
P.MsgId = MsgId &
(P.Kind = OpRequest &
MsgName(Text) = ResponseToOpRequest =>
ProcessedResponse(P, Text, Source)
<> Error))
<> (MsgName(Text) = OperatorRequest =>
N"Answers = Answers; (ClockRead, Text)
<> Error))}
transform MsgDump(MsgId: MessageId, Text: String, Source: ProcessName)
refcond Source = DumpProcessor

effect (E"P:PendingRequest(P<:PendingRequests & P.MsgId = MsgId) =>
    E"P:PendingRequest(P<:PendingRequests & P.MsgId = MsgId &
    (P.Kind = OpRequest &
    MsgName(Text) = ResponseToOpRequest =>
    ProcessedResponse(P, Text, Source) => Error))
    => (MsgName(Text) = OperatorRequest =>
    N"Answers = Answers.(ClockRead, Text) => Error))
transform MsgAcnt(MsgId: MessageId, Text: String, Source: ProcessName)

refcond Source = AcntProcess

effect (E"P:PendingRequest(P,<PendingRequests & P.MsgId = MsgId) =>
    E"P:PendingRequest(P,<PendingRequests & P.MsgId = MsgId &
    P.Kind = OpRequest &
    MsgName(Text) = ResponseToOpRequest =>
    ProcessedResponse(P,Text,Source)
    => Error))

    => (MsgName(Text) = OperatorRequest =>
    "Answers = Answers. (ClockRoad, Text)
    => Error))
transform MsgAuth(MsgId, MessageId, Text: String, Source: ProcessName)

refcond Source = AuthProcess

effect (E"P: PendingRequest(P<:PendingRequests & P.MsgId = MsgId) => E"P: PendingRequest(P<:PendingRequests & P.MsgId = MsgId) & (P.Kind = OpRequest => (MsgName(Text) = ResponseToOpRequest =>ProcessedResponse(P, Text, Source) <= Error) => P.Kind = MapUserId => (MsgName(Text) = MappedUserId => (P.Command<:Cat3 => OpCat3(P.Command, Nkcs(Text)) => P.Command = ACNT+USERIDS => OpCat7(P.Command, Nkcs(Text))) => Error) <= Error)

<= Error))

<= (MsgName(Text) = OperatorRequest => "Answer = Answers:. (ClockRead, Text)

<= MsgName(Text) = AddNkcp => AUTH1(Nkcs(Text))
<= MsgName(Text) = DeleteNkcp => AUTH2(Nkcs(Text))

<= Error))}
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transform MsgNet(MsgId: MessageId,
Text: String,
Source: ProcessName)

refcond Source = NetworkProcess

effect (E"P:PendingRequest(P<P:PendingRequests &
P.MsgId = MsgId) =>
E"P:PendingRequest(P<P:PendingRequests &
P.MsgId = MsgId &
(P.Kind = OpRequest =>
(MsgName(Text) = ResponseToOpRequest =>
ProcessedResponse(P,Text,Source)
&
Error)
" P.Kind = PrintOpMsg =>
(MsgName(Text) = OpMsgPrinted =>
(Answers = nil =>
N"ConsoleOutputState = Idle
&
N"ConsoleOutputState = Continuing
&
N"Answers = Answers:2)
" MsgName(Text) = OpHitAttn =>
N"CommandExpected
&
N"ConsoleOutputState = Idle
&
KernelCalled(SendMessage(NetworkProcess))
&
Error)
" P.Kind = ReadOpRequest =>
(MsgName(Text) = OpRequestRead =>
ProcessedCommand(Text)
&
(CommandExpected
&
ConsoleOutputState = Idle
&
Answers => nil =>
KernelCalled(SendMessage(NetworkProcess))
&
N"Answers = Answers:2
&
N"ConsoleOutputState = Continuing
" N"Answers = Answers
&
N"ConsoleOutputState = ConsoleOutputState)"
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3.1.2 Operator Process (Formal)

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<< MsgName(Text) = OphitAttn =>
   "CommandExpected"
   &
   "ConsoleOutputState = Idle"
   &
   KernelCalled(SendMessage(NetworkProcess))
<< Error)
<< Error))
<< (MsgName(Text) = OperatorRequest =>
   "Answers = Answers1. (ClockRead, Text)
<< MsgName(Text) = OphitAttn =>
   "CommandExpected"
   &
   "ConsoleOutputState = Idle"
   &
   KernelCalled(SendMessage(NetworkProcess))
<< Error))

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transform OpDriver(InterruptType, InterruptSubType, MsgId: MessageId, Text: String, Source: ProcessName)

effect (InterruptType = ExternalInterrupt) =>
  (InterruptSubType = Message =>
   KernelCalled(ReceiveMessage) &
   (Source = AuthProcess =>
    MsgAuth(MsgId, Text, Source)
   => Source = URProcess =>
    MsgUR(MsgId, Text, Source)
   => Source = IDPScheduler =>
    MsgIDPS(MsgId, Text, Source)
   => Source = IOScheduler =>
    MsgIOS(MsgId, Text, Source)
   => Source = NetworkProcess =>
    MsgNet(MsgId, Text, Source)
   => Source = DumpProcessor =>
    MsgDump(MsgId, Text, Source)
   => Source = TrustedProcesses =>
    S"(IDPScheduler, IOScheduler, NetworkProcess, DumpProcessor) =>
    MsgNkcp(MsgId, Text, Source)
   => Error)
  => Error)

  KernelCalled(ReceiveInterrupts)
  &
  KernelCalled(ReleaseCPU)

end OpProcess
3.2.1 Unit Record Process
Informal Description

This section contains the informal description of the Unit Record Process of KVM/378.

Overview

The Unit Record Process (URProcess) performs four main functions:

1. routes readers to the appropriate NKCP input spool file processor;
2. controls the allocation of printers and punches to NKCP output spool file processors;
3. processes operator commands dealing with spool files or unit record devices; and
4. controls the allocation of all unit record devices and tapes.

Input Spool Files

The Unit Record Process receives an external interrupt from the Kernel which tells the Unit Record Process that a particular card reader is ready to transfer card images. The Unit Record Process initiates a single-card read, which causes the identification card to be read. This identification card contains (at least) the security level of the information in the file. The Unit Record Process attaches the device to the appropriate NKCP and sends a message to the NKCP controlling this security level, notifying the NKCP that an input file awaits spooling. When the NKCP's input spool file processor has completed the transfer it notifies the Unit Record Process, which in turn detaches the input device.

Output Spool Files

When the output spool file processor of an NKCP wishes to print or punch a (set of) spool file(s), it sends a message to that effect to the Unit Record Process, which in turn enters the NKCP in a list of NKCPs awaiting a real device. When an appropriate device becomes available, the Unit Record Process causes the device to be readied for the new security level (possibly by the operator, according to installation policy), attaches the device to the NKCP, and notifies the NKCP. When the NKCP is finished with the device, it notifies the Unit Record Process, which detaches the device from the NKCP. The Unit Record Process then marks the device as available, allowing the cycle to begin anew.
Operator Commands

Operator commands regarding spool files or unit record devices are sent by the Operator Process to the Unit Record Process for processing. Most information about spool files is distributed in the NKCPs. Thus the Unit Record Process processes operator commands dealing with spool files by sending messages to the NKCPs and awaiting their responses. It then gathers the responses and prepares one message for the Operator Process, which will cause the response to be printed on the operator's console.

Each operator command processed by the Unit Record Process is discussed below. Figures 1 through three display the various processing cycles of the unit record devices.
Figure 1

THE HEADER SPOOLING CYCLE
Figure 2

Printer and Punch

Spooling Cycles
Figure 3
NON-SPOOLING CYCLES FOR ALL UNIT RECORD DEVICES
## Operator Commands

### sent first to Unit Record Process

<table>
<thead>
<tr>
<th>Command</th>
<th>S/M</th>
<th>Map</th>
<th>Category</th>
<th>Destination(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUERY-UR</td>
<td>Both</td>
<td>-</td>
<td>0</td>
<td>Attached Processes</td>
</tr>
<tr>
<td>QUERY-ALL</td>
<td>Both</td>
<td>-</td>
<td>0</td>
<td>Attached Processes</td>
</tr>
<tr>
<td>QUERY-RADAR</td>
<td>Both</td>
<td>-</td>
<td>0</td>
<td>Attached Processes</td>
</tr>
<tr>
<td>QUERY-TAPES</td>
<td>Both</td>
<td>-</td>
<td>0</td>
<td>Attached Processes</td>
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<tr>
<td>QUERY-FILES-USERID</td>
<td>S</td>
<td>U-&gt;N</td>
<td>3</td>
<td>NKCP</td>
</tr>
<tr>
<td>QUERY-FILES-ALL</td>
<td>M</td>
<td>-</td>
<td>2</td>
<td>all NKCPs</td>
</tr>
<tr>
<td>QUERY-READER-USERID</td>
<td>S</td>
<td>U-&gt;N</td>
<td>3</td>
<td>NKCP</td>
</tr>
<tr>
<td>QUERY-READER-SPoolID</td>
<td>S</td>
<td>-</td>
<td>1</td>
<td>NKCP</td>
</tr>
<tr>
<td>QUERY-READER-ALL</td>
<td>M</td>
<td>-</td>
<td>2</td>
<td>all NKCPs</td>
</tr>
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<td>S</td>
<td>U-&gt;N</td>
<td>3</td>
<td>NKCP</td>
</tr>
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<td>-</td>
<td>1</td>
<td>NKCP</td>
</tr>
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<td>QUERY-PRINTER-ALL</td>
<td>M</td>
<td>-</td>
<td>2</td>
<td>all NKCPs</td>
</tr>
<tr>
<td>QUERY-PUNCH-USERID</td>
<td>S</td>
<td>U-&gt;N</td>
<td>3</td>
<td>NKCP</td>
</tr>
<tr>
<td>QUERY-PUNCH-SPoolID</td>
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<td>-</td>
<td>1</td>
<td>NKCP</td>
</tr>
<tr>
<td>QUERY-PUNCH-ALL</td>
<td>M</td>
<td>-</td>
<td>2</td>
<td>all NKCPs</td>
</tr>
<tr>
<td>QUERY-HOLD</td>
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<td>-</td>
<td>2</td>
<td>all NKCPs</td>
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<td>SHUTDOWN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BACKSPACE</td>
<td>S</td>
<td>-</td>
<td>4</td>
<td>Attached Processes</td>
</tr>
<tr>
<td>CHANGE-USERID</td>
<td>S</td>
<td>U-&gt;N</td>
<td>3</td>
<td>NKCP</td>
</tr>
<tr>
<td>CHANGE-SYSTEM-CLASS-ALL</td>
<td>M</td>
<td>-</td>
<td>2</td>
<td>all NKCPs</td>
</tr>
<tr>
<td>CHANGE-SYSTEM-SPoolID</td>
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<td>-</td>
<td>1</td>
<td>NKCP</td>
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<tr>
<td>DRAIN</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>FLUSH</td>
<td>S</td>
<td>-</td>
<td>4</td>
<td>Attached Processes</td>
</tr>
<tr>
<td>FREE</td>
<td>S</td>
<td>U-&gt;N</td>
<td>3</td>
<td>NKCP</td>
</tr>
<tr>
<td>HOLD</td>
<td>S</td>
<td>U-&gt;N</td>
<td>3</td>
<td>NKCP</td>
</tr>
<tr>
<td>ORDER-USERID</td>
<td>S</td>
<td>U-&gt;N</td>
<td>3</td>
<td>NKCP</td>
</tr>
<tr>
<td>ORDER-SYSTEM</td>
<td>Both</td>
<td>-</td>
<td>6</td>
<td>some NKCPs</td>
</tr>
<tr>
<td>PURGE-USERID</td>
<td>S</td>
<td>U-&gt;N</td>
<td>3</td>
<td>NKCP</td>
</tr>
<tr>
<td>PURGE-SYSTEM</td>
<td>Both</td>
<td>-</td>
<td>6</td>
<td>some NKCPs</td>
</tr>
<tr>
<td>REPEAT</td>
<td>S</td>
<td>-</td>
<td>4</td>
<td>Attached Process</td>
</tr>
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<td>SPACE</td>
<td>S</td>
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<td>5</td>
<td>Attached Process</td>
</tr>
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<td>START</td>
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<td>TRANSFER</td>
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</tr>
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<td>ATTACH</td>
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<td>DETACH</td>
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<td>LOADBUF</td>
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<td></td>
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</tr>
<tr>
<td>VARY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOCATE</td>
<td>S</td>
<td>-</td>
<td>7</td>
<td>Attached Process</td>
</tr>
</tbody>
</table>
Dedicated Device Attachment

The Unit Record Process also oversees the assignment of unit record devices and tapes in nonsharable status to VMs. There are two ways a user can initiate the attachment of a dedicated device. At logon time, the Authorization Process will automatically request device attachment if a permanent device attachment request exists in the user's directory entry. The user may also request device attachment from the operator who will send the request on to the Unit Record Process. In either case, the device must be available for assignment (i.e., not attached to some other process and in the case of readers, printers, and punches, not involved in spooling operations) and must meet security requirements. The Unit Record Process performs the attachment if it can and notifies the requesting process of the result. (Further details can be found in a later section.)

More on Readers

Each reader's initial state is either "Drained, Available" or "NotAvailableForSpooling, OffLine," depending on the system configuration information provided by the Authorization Process.

The "Drained, Available" state provides the link between the spooling and nonspooling cycles: to be employed in a nonspooling capacity, a device must first reach this state. For example, the DRAIN command must be issued for a device before it can be attached to a user, or varied offline.

A device can be entered into the spooling cycle by issuing the START command. The reader's associated state then becomes "Started, Available." The very first time the START command is issued, a list of file classes the device may process must be provided.

A Walk Around the Reader Spooling Cycle

The operator first issues the START command, providing a list of file classes which the reader may process.

The operator then loads a deck of cards into the reader's hopper and presses the read button. The resulting "Ready" interrupt ("Device End") causes a state transition from "Started, Available" to "Started, SecurityHeader". The Unit Record Process initiates a card read operation to read in the header card that contains the security level of the deck.

The interrupt generated by the end of the card causes the next state change. If there is no read error, the Unit Record Process attaches the device to the NKCP which should process this security level. The state changes to "Started, SpoolingForProcess."
there is a read error, the Unit Record Process notifies the operator that physical intervention is required by sending a message to the Operator Process. The Unit Record Process then updates its state information for this reader to reflect that a wait for a "Device Ready" interrupt is necessary. Upon receipt of this interrupt (caused by the operator again pushing the read button), the Unit Record Process reissues its request for input of the header card.

If the appropriate NKCP does not currently exist, the Unit Record Process asks the Authorization Process to create it. The state becomes "Started, AttachPending." When the reader has reached this state, further processing awaits the receipt of a message from the Authorization Process stating whether or not the NKCP was created.

Once the reader is under the control of the NKCP, the Unit Record Process updates the status of the reader to "Started, SpoolingForProcess." The Unit Record Process pays no more attention to the reader until the controlling NKCP explicitly requests its release.

For various reasons the Unit Record Process can reject the request that the reader be attached to an NKCP. These reasons include:

- the reader is not cleared to read this deck (operator error); or
- the NKCP which should read this deck does not currently exist, and for some reason the Authorization Process is not going to create it.

In these cases, the Unit Record Process returns the device to the "Available" state and sends a message to the Operator Process asking the operator to physically flush the deck from the reader.

If the attach succeeds and the card deck is processed by some NKCP, the Unit Record Process will next receive a release request from the NKCP. At this point, the Unit Record Process detaches the device from the NKCP, and updates the device status to "Started, Available". The cycle is then complete.
A More Detailed View of Dedicated Device Attachment

At logon, the Authorization Process attempts to attach to the new VM each of the devices listed in the dedicated device section of the directory entry for the user logging on. (See the description of the Authorization Process for a detailed view of the directory and its contents.) If the device being requested is either a unit record device or a tape drive, the Authorization Process, after examining the security conditions of the attachment, requests that the actual assignment be performed by the Unit Record Process. The Unit Record Process determines if the device is available (not attached to any other process, and if a unit record device, drained), and attaches the device if it can. It informs the Authorization Process of the result. The Unit Record Process does not directly notify the NKCP, since the Authorization Process will inform the NKCP of the device attachment at the same time it tells the NKCP about the new VM.

When the NKCP is finished with the device (because the user performed an explicit detach or because he or she logged off), the NKCP is expected to directly notify the Unit Record Process which will update its status information and detach the device from the NKCP.

The other method of attaching a device for nonsharable use requires that the user send a message to the system operator who decides if such an attachment should be performed. The operator first ensures the device is available and/or drained, and then types the operator command 'Attach' with the appropriate parameters. If the device is a unit record device or a tape drive, the Operator Process reflects the message to the Unit Record Process. The Unit Record Process determines whether the device is available and/or drained, and whether or not the process and device have compatible security levels given the requested access. If these conditions are met, the Unit Record Process performs the attachment. If the attachment is performed, the Unit Record Process informs both the operator and the affected NKCP. If it cannot be performed, the Unit Record Process informs only the operator. If the operator then decides that the device is not currently assignable to the NKCP, it is up to him or her to so inform the NKCP. Again, when the NKCP is finished with the device, it directly informs the Unit Record Process which releases the assignment.

In summary, dedicated unit record or tape drive device attachment is performed either at logon time or by operator request, rather than by the user directly requesting attachment from the Unit Record Process. However, device detachment is directly requested of the Unit Record Process.
QUERY

"Provide status information on the real or virtual machine, and miscellaneous CP functions."

UR, ALL - for each device in each device table:
  if device is currently attached to NKCP:
    reflect message to NKCP
    prepare response from status information
    and NKCP response
  else:
    prepare response from status information
    send response to Operator Process

raddr - [raddr must be unit record device]
  if device is currently attached to NKCP:
    reflect message to NKCP
    prepare response from status information
    and NKCP response
  else:
    prepare response from status information
    send response to Operator Process

FILES - user id - map user id to NKCP Id
         reflect message to NKCP
         send NKCP response to Operator Process

[ALL] - reflect message to each NKCP
        gather responses
        send amalgamated response to Operator Process

READER, PRINTER, PUNCH -
  user id - map user id to NKCP Id
  reflect message to NKCP
  send NKCP response to Operator Process

spool id - [syntax has been extended to provide NKCP ids along with all spool ids]
  reflect message to NKCP
  owning spool file
  send NKCP response to Operator Process
3.2.1 Unit Record Process (Informal)

[ALL] - reflect message to each NKCP
gather responses
send amalgamated response
to Operator Process

HOLD - reflect message to each NKCP
gather responses
send amalgamated response to Operator Process

BACKSPAC
"Restart or backspace the output of a unit record spooling
device."
[device must be printer or punch;
must be assigned to Process]
reflect message to Process owning device
send Process response to Operator Process

CHANGE
"Alter one or more attributes of a closed spooled file."
user id - map user id to NKCP id
reflect message to NKCP
send NKCP response to Operator Process

SYSTEM - if "CLASS" or "ALL" specified:
reflect message to each NKCP
gather responses
send amalgamated response
to Operator Process
else: (spool id specified)
syntax has been extended to
provide NKCP ids along with
all spool ids
reflect message to NKCP owning spool file
send NKCP response to Operator Process

DRAIN
"Stop spooling activity on the specified devices after the
current files in operation reach termination."
update appropriate device table entries
reflect message to each Process
owning an affected device,
if no message has already been sent
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3.2.1 Unit Record Process (Informal)  TM-6062/101/88

GATHER
send amalgamated response to Operator Process

FLUSH
"Eliminate and halt the current file output on the specified real unit record device."
[device must be printer or punch; must be assigned to Process]
reflect message to Process owning device
send Process response to Operator Process

FREE
"Release spool HOLD status from previously held files for real reader, printer, and punch devices."
map user id to NKCP id
reflect message to NKCP
send NKCP response to Operator Process

HOLD
"Defer file output to the real reader, printer, and punch devices."
map user id to NKCP id
reflect message to NKCP
send NKCP response to Operator Process

ORDER
"Redefine the order of closed spool files."
user id - map user id to NKCP id
reflect message to NKCP
send NKCP response to Operator Process
SYSTEM - determine concerned NKCPs
reflect message to each
gather responses
send amalgamated response to Operator Process

PURGE
"Remove spooled file(s) before reading, punching, or printing."

user id - map user id to NKCP id
reflect message to NKCP
send NKCP response to Operator Process

SYSTEM - determine concerned NKCPs
reflect message to each
gather responses
send amalgamated response to Operator Process

REPEAT

"Add to the number of copies of an output printer or punch file on a real unit record device."

[raddr must be a printer or punch; must be assigned to an NKCP]
reflect message to Process owning device
send Process response to Operator Process

SPACE

"Force single space on the printer, regardless of carriage control codes contained in the file."

[raddr must be a printer; must be assigned to an NKCP]
reflect message to Process owning device
send Process response to Operator Process

START

"Start unit record devices, or restart drained devices, or restart and change output classes that may be serviced."

update appropriate device table entry
send response to Operator Process

TRANSFER

"Direct an input spool file to or retrieve it from a specified user's virtual card reader."

[syntax has been extended to provide NKCP id along with all user ids]
user id, SYSTEM spool id -
  TO user id, FROM user id -
    if source NKCP = destination NKCP:
      reflect message to source NKCP
    send NKCP response to Operator Process
  else:
    send "Illegal" message to Operator Process
FROM ALL - not allowed in KVM/370
SYSTEM ALL -
  TO user id - not allowed in KVM/370
  FROM user id - [same as SYSTEM spool id FROM user id]

ATTACH

"Attach a real device to a virtual machine or the real system."

[raddr must be a unit record device; device must be in a DRAINED state]
KernelCall: GrantAccess
update appropriate device table entry
send response to Operator Process

DETACH

"Remove a real or virtual device or channel from a virtual machine or the real system."

[raddr must be a unit record device; device must be in a DRAINED state]
KernelCall: ReleaseDevice
update appropriate device table entry
send response to Operator Process

LOADBUF

"Load a specified train image into either the 1403 universal character set buffer or the 3211 universal character set or form control buffers."

[raddr must be a printer in a DRAINED state]
if device is currently attached to NKCP:
  reflect message to NKCP
  send NKCP response to Operator Process
else:
  update appropriate device table entry

VARY

"Allow or disallow the availability of a device to the VM/370 control program."

raddr - [raddr must be a unit record device]
  update appropriate device table entry
  if device is attached to Process, notify Process
  send response to Operator Process

LOCATE

"Provide the starting location of the user's CP control blocks or (virtual or real) devices."

raddr - [raddr must be a unit record device; device must be assigned to NKCP]
  reflect message to NKCP owning device
  send NKCP response to Operator Process
Authorization Process
- Responses -

AddedNkcp
CannotAddNkcp
UserIdMapped

Authorization Process
- Requests -

AttachDevice
DeleteNkcp

NKCP Requests

AssignSpoolDevice
ReleaseSpoolDevice
DetachDevice

NKCP Responses

ResponseToOpRequest
DetachDevice
module URProcess

type
DeviceAddress,
Char,
String = list of Char,
HardwareStatus,
MessageId,
ProcessName,
Class,
ResponseStatus = (NoResponse, Responded),
ReqDevRequestStatus = (NoNeed, ShouldSend, Sent),
CommandName = (QUERY-UR-ALL, QUERY-RAADDR, QUERY-FILES-USERID, QUERY-FILES-ALL, QUERY-ROPSPU-USERID, QUERY-ROPSPU-POOLID, QUERY-ROPSPU-ALL, QUERY-OPOL, BACKSPAC, CHANGE-USERID, CHANGE-ITEM, CLEAR, FREE, HOLD, ORDER-USERID, ORDER-SYSTEM, PURGE-USERID, PURGE-SYSTEM, REPEAT, SPACE, TRANSFER, LOCATE-RADDR),
RequestCategory = (OpRequest, MapUserld, NeedNkcp, RelinquishDevice),
InputDeviceStatus = (SecurityHeader, SecurityHeaderWaitForReady, AttachedPending, AttachedToSpoolProcess, Available, AttachedToUser, DetachPending, Offline),
TapeDriveStatus = (Available, AttachedToUser, Offline, DetachPending),
ActivityStatus = (NotSpooling, Drained, Started, Draining),
Spoolid = structure of
  Process = ProcessName,
  File = T:"I:integer(0 <= I & I <= 999)),
ODRequestStatus = (Processing, WaitingForDevice),
OutputDeviceRequest = structure of (  
    Process = ProcessName,  
    RequestedClasses = set of Class,  
    AttachedDevice = DeviceAddress,  
    State = ODRequestStatus),  

TapeDriveEntry = structure of (  
    Raddr = DeviceAddress,  
    State = TapeDriveStatus,  
    AttachedProcess = ProcessName),  

ResponseSlot = structure of (  
    Respondent = ProcessName,  
    Text = String,  
    State = ResponseStatus),  

PendingRequest = structure of (  
    MsgId = MessageId,  
    Kind = RequestCategory,  
    Command = CommandName,  
    Responses = set of ResponseSlot),  

ReaderEntry = structure of (  
    Raddr = DeviceAddress,  
    State = ActivityStatus,  
    CyclePosition = InputDeviceStatus,  
    AttachedProcess = ProcessName,  
    ClassesServedCurrently = set of Class,  
    ClassesServedNextCycle = set of Class,  
    ChannelStatusWord = HardwareStatus,  
    LineBuffer = String),  

PrinterEntry = structure of (  
    Raddr = DeviceAddress,  
    State = ActivityStatus,  
    CyclePosition = OutputDeviceStatus,  
    AttachedProcess = ProcessName,  
    ClassesServedCurrently = set of Class,  
    ClassesServedNextCycle = set of Class,  
    RelinquishDeviceRequestState = RelDevRequestStatus,  
    ChannelStatusWord = HardwareStatus),  

PunchEntry = structure of (  
    Raddr = DeviceAddress,  
    State = ActivityStatus,  
    CyclePosition = OutputDeviceStatus,  
    AttachedProcess = ProcessName,  
    ClassesServedCurrently = set of Class,  
    ClassesServedNextCycle = set of Class,  
    RelinquishDeviceRequestState = RelDevRequestStatus,  
    ChannelStatusWord = HardwareStatus)
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3.2.2 Unit Record Process (Formal)  TM-6062/101/00

NkcpEntry = structure of (  
  Process = ProcessName,
  UsableReaders = set of DeviceAddress,
  UsablePrinters = set of DeviceAddress,
  UsablePunches = set of DeviceAddress,
  UsableTapeDrives = set of DeviceAddress)

type
  MessageLabel = (AddedNkcp, CannotAddNkcp, UserIDMapped,
                  AddNkcp, DeleteNkcp, AttachDevice),

DeviceTypes,
KernelFunction,

Cat0 = T" (QUERY-UR, QUERY-ALL, QUERY-ADDR, QUERY-TAPES),

Cat1 = T" (QUERY-READER-SPoolID, QUERY-PRINTER-SPoolID,
          QUERY-PUNCH-SPoolID, CHANGE-SYSTEM-SPoolID),

Cat2 = T" (QUERY-FILES-ALL, QUERY-READER-ALL, QUERY-PRINTER-ALL,
          QUERY-PUNCH-ALL, QUERY-HOLD, CHANGE-SYSTEM-CLASS-ALL),

Cat3 = T" (QUERY-FILES-USERID, QUERY-READER-USERID, QUERY-PRINTER-USERID,
          QUERY-PUNCH-USERID, CHANGE-USERID, FREE, HOLD, ORDER-USERID,
          PURGE-USERID),

Cat4 = T" (BACKSPACE, FLUSH, REPEAT),

Cat6 = T" (ORDER-SYSTEM, PURGE-SYSTEM)

constant
  MsgName (String):MessageLabel,
  DeviceType (DeviceAddress):DeviceTypes,
  Raddr (String):DeviceAddress,
  NewMsgId:MessageId,
  SendMessage (ProcessName):KernelFunction,
  DefinedElsewhere:boolean = true,
  Nkcps (String):set of ProcessName,
  OpCmd (String):CommandName,
  TrustedProcesses = S" (OpProcess, URProcess, AuthProcess,
                             AcntProcess, UpdaterProcess)
variable
ShuttingDown: boolean,
Readers: set of ReaderEntry,
Printers: set of PrinterEntry,
Punches: set of PunchEntry,
TapeDrives: set of TapeDriveEntry,
PrinterSpoolRequests: set of OutputDeviceRequest,
PunchSpoolRequests: set of OutputDeviceRequests,
CurrentNkcp: set of NkcpEntry,
PendingRequests: set of PendingRequest
Initial
PendingRequests = Empty
&
CurrentNkcps = Empty
&
PrinterSpoolRequests = Empty
&
ShuttingDown
&
A"R:ReaderEntry(R<:Readers ->
(\(\text{R.State} = Drained\)
&
R.CyclePosition = Available
&
R.AttachedProcess = URProcess
&
R.LineBuffer = nil
&
R.ClassesServedCurrently = Empty
&
R.ClassesServedNextCycle = Empty))
&
A"P:PrinterEntry(P<:Printers ->
(\(\text{P.State} = Drained\)
&
P.CyclePosition = URProcess
&
P.AttachedProcess = URProcess
&
P.ClassesServedCurrently = Empty
&
P.ClassesServedNextCycle = Empty
&
P.RelinquishDeviceRequestState = NoNeed))
&
A"P:PunchEntry(P<:Punches ->
(\(\text{P.State} = Drained\)
&
P.CyclePosition = URProcess
&
P.AttachedProcess = URProcess
&
P.ClassesServedCurrently = Empty
&
P.ClassesServedNextCycle = Empty
&
P.RelinquishDeviceRequestState = NoNeed))
&
A"T:TapeDriveEntry(T<:TapeDrives ->
(\(\text{T.State} = Available\)
&
T.AttachedProcess = URProcess))
invariant
A"R1,R2:ReaderEntry(R1<:Readers & R2<:Readers ->
(R1.Raddr = R2.Raddr -> R1 = R2))
&
A"Pr1,Pr2:PrinterEntry(Pr1<:Printers & Pr2<:Printers ->
(Pr1.Raddr = Pr2.Raddr -> Pr1 = Pr2))
&
A"Pu1,Pu2:PunchEntry(Pu1<:Punches & Pu2<:Punches ->
(Pu1.Raddr = Pu2.Raddr -> Pu1 = Pu2))
&
A"T1,T2:TapeDriveEntry(T1<:TapeDrives & T2<:TapeDrives ->
(T1.Raddr = T2.Raddr -> T1 = T2))
&
A"R:ReaderEntry, Pr:PrinterEntry, Pu:PunchEntry, T:TapeDriveEntry
(R<:Readers & Pr<:Printers & Pu<:Punches & T<:TapeDrives ->
&
Pr.Raddr = Pu.Raddr & Pr.Raddr = T.Raddr
&
Pu.Raddr = T.Raddr)
&
A"R:ReaderEntry(R<:Readers ->
(R.State = NotSpooling =>
(R.CyclePosition<:S"(AttachPending, DetachPending,
AttachedToUser, OffLine)
<> R.CyclePosition<:S"(SecurityHeader, SecurityHeaderWaitForReady,
AttachPending, AttachedToSpoolingProcess, Available))
&
(R.CyclePosition = Available ->
(R.ClassesServedCurrently = R.ClassesServedNextCycle
&
R.AttachedProcess = URProcess)))
&
A"P:PrinterEntry(P<:Printers ->
(P.State = NotSpooling =>
P.CyclePosition<:S"(AttachPending, DetachPending,
AttachedToUser, OffLine)
<> P.CyclePosition<:S"(SecurityHeader, SecurityHeaderWaitForReady,
SecurityTrailer, SecurityTrailerWaitForReady,
AttachedToSpoolingProcess, Available))
&
(P.CyclePosition = Available ->
(P.ClassesServedCurrently = P.ClassesServedNextCycle
&
P.AttachedProcess = URProcess)))
&
A"P:PunchEntry(P<:Punches ->

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((P.State = NotSpooling =>
  P.CyclePosition<:<"(AttachPending, DetachPending,
    AttachedToUser, Offline)
  <> P.CyclePosition<:<"(SecurityHeader,
    SecurityHeaderWaitForReady,
    SecurityTrailer,
    SecurityTrailerWaitForReady,
    AttachedToSpoolingProcess, Available))

&P.CyclePosition = Available =>
  (P.ClassesServedCurrently = P.ClassesServedNextCycle
   &
   P.AttachedProcess = URProcess)))

&P: OutputDeviceRequests((OR:<:PrinterSpooolRequests
  |
  OR:<:PunchSpoolRequests) =>
  (E:"N: NkcpEntry(N<:<CurrentNkcps &
    N.Process = OR.Process)))

&P1=N1,N2:NkcpEntry(N1<:<CurrentNkcps & N2<:<CurrentNkcps =>

&P: NkcpEntry(N<:<CurrentNkcps =>
  (A"D:DeviceAddress
    ((D<:<N.UsableReaders =>
      E"R:ReaderEntry(R<:<Readers &
        D = R.Raddr)
    <> D<:<N.UsablePrinters =>
      E"Pr:PrinterEntry(Pr<:<Printers &
        D = Pr.Raddr)
    <> D<:<N.UsablePunches =>
      E"Pu:PunchEntry(Pu<:<Punches &
        D = Pu.Raddr)
    <> D<:<N.UsableTapeDrives =>
      E"T:TapeDriveEntry(T<:<TapeDrives &
        D = T.Raddr))))}

&P1,P2:PendingRequests(P1<:<PendingRequests & P2<:<PendingRequests =>
  (P1.MsgId = P2.MsgId => P1 = P2))

&P: PendingRequests(P<:<PendingRequests =>
  (A"R1,R2:ResponseSlot(R1<:<P.Responses & R2<:<P.Responses =>
    (R1.Respondent = R2.Respondent => R1 = R2))))
transform KernelCalled(K:KernelFunction)
effect true
transform RD(DeviceAddress)

refcond E"R:ReaderEntry(R<:Readers & R.Raddr = Raddr)

effect E"R:ReaderEntry(R<:Readers & R.Raddr = Raddr &
(R.State<:S"(NotSpooling,Drained)
R.CyclePosition<:S"(AttachPending,AttachedToSpoolingProcess,
AttachedToUser,DetachPending,OffLine) =>

Error

<> (R.CyclePosition = SecurityHeader =>
(R.ChannelStatusWord.UnitCheck =>
R02b
<> R02a)
<> R.CyclePosition = SecurityHeaderWaitForReady =>
(R.ChannelStatusWord.UnitCheck =>
R02b
<> R02c)
<> R.CyclePosition = Available =>
(ShuttingDown =>
KernelCalled(SendMessage(OpProcess))
<> R01(Raddr))))
transform \text{PR(Raddr:DeviceAddress)}

\text{refcond } \text{E"P:PrinterEntry(P<:Printers \& P.Raddr = Raddr" )}

\text{effect } \text{E"P:PrinterEntry(P<:Printers \& P.Raddr = Raddr \& (P.State<:S"(NotSpooling,Drained) \&

\text{P.CyclePosition<:S"(AttachedToSpoolingProcess, AttachedToUser,DetachPending,OffLine) \Rightarrow}

\text{Error}

\langle (P.CyclePosition = SecurityHeader \Rightarrow

\text{(P.ChannelStatusWord.UnitCheck \Rightarrow PR3b

\Rightarrow PR3a))

\langle P.CyclePosition = SecurityHeaderWaitForReady \Rightarrow

\text{(P.ChannelStatusWord.UnitCheck \Rightarrow PR3b

\Rightarrow PR3c))

\langle P.CyclePosition = Available \Rightarrow

\text{(PrinterSpoolRequests \Leftarrow Empty \&

\text{P.State = Started \&

\text{E"DR:OutputDeviceRequest(DR<:PrinterSpoolRequests \Leftarrow

\text{(DR.State = WaitingForDevice \&

\text{P.ClassesServedCurrently \& DR.RequestedClasses \Leftarrow Empty \Rightarrow

PR2)))

\langle P.CyclePosition = SecurityTrailer \Rightarrow

\text{(P.ChannelStatusWord.UnitCheck \Rightarrow PR5a

\Rightarrow PR5b

\langle P.CyclePosition = SecurityTrailerWaitForReady \Rightarrow

\text{(P.ChannelStatusWord.UnitCheck \Rightarrow PR5b

\Rightarrow PR5c))}})

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3.2.2 Unit Record Process (Formal)

transform PU(Raddr:DeviceAddress)

refcond E"PiPunchEntry(Px:Punches &
   P.Raddr = Raddr)

effect E"PiPunchEntry(Px:Punches &
   P.Raddr = Raddr &
   (P.State<>S"(NotSpooling,Drained)
   &
   P.CyclePosition<>S"(AttachedToSpoolingProcess,
      AttachedToUser,DetachPending,OffLine) =>
      Error
   <> (P.CyclePosition = SecurityHeader =>
      (P.ChannelStatusWord.UnitCheck =>
      PU3b
      <> PU3a)
   <> P.CyclePosition = SecurityHeaderWaitForReady =>
      (P.ChannelStatusWord.UnitCheck =>
      PU3b
      <> PU3c)
   <> P.CyclePosition = Available =>
      (PunchSpoolRequests => Empty
      &
      P.State = Started
      &
      E"OR:OutputDeviceRequest(OR<PunchSpoolRequests =>
      (OR.State = WaitingForDevice
      &
      P.ClassesServedCurrently & ORRequestedClasses
      => Empty =>
      PU2))))
   <> P.CyclePosition = SecurityTrailer =>
      (P.ChannelStatusWord.UnitCheck =>
      PU5b
      <> PU5a)
   <> P.CyclePosition = SecurityTrailerWaitForReady =>
      (P.ChannelStatusWord.UnitCheck =>
      PU5b
      <> PU5c))))

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transform MsgAuth(MsgId: MessageId,
Text: String,
Source: ProcessName)
rcfcond Source = AuthProcess
effect (E"P:PendingRequest(P:<PendingRequests &
P.MsgId = MsgId) =>
(E"P:PendingRequest(P:<PendingRequests & P.MsgId = MsgId &
(P.Kind = NeedNkcp =>
(MsgName(Text)) = AddNkcp =>
R03a(Raddr(Text)))
&
N"PendingRequests = PendingRequests :: S"(P)
<> MsgName(Text) = CannotAddNkcp =>
R03b(Raddr(Text))
&
N"PendingRequests = PendingRequests :: S"(P)
<> Error)
<> P.Kind = MapUserId =>
(MsgName(Text)) = UserIDMapped =>
(MsgName(Text)) = nil =>
KernelCalled(SendMessage(OpProcess))
&
N"PendingRequests = PendingRequests
:: S"(P)
<> KernelCalled(SendMessage(Nkcp(Text)))
&
N"PendingRequests = PendingRequests
:: S"(P) "
S"((NewMsgId,
OpRequest,
OpCmd(Text),
S"((Nkcp(Text),
nil,
NoResponse))))
<> Error)
<> Error))
<> /* message is a request, not a response */
(MsgName(Text)) = AddNkcp =>
AUTH1
<> MsgName(Text) = DeleteNkcp =>
AUTH2
<> MsgName(Text) = AttachDevice =>
(DeviceType(Raddr(Text)) = Reader =>
AUTH3a(Raddr(Text)))
<> DeviceType(Raddr(Text)) = Printer =>
AUTH3b(Raddr(Text))
<> DeviceType(Raddr(Text)) = Punch =>
AUTH3c(Raddr(Text))
<> DeviceType(Raddr(Text)) = TapeDrive =>
AUTH3d(Raddr(Text))
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<> Error
<> Error)}

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transform MsgOp(MsgId: MessageId, 
   text: String, 
   Source: ProcessName)

refcond Source = AuthProcess

effect (E*P:PendingRequest(P<PendingRequests & 
P.MsgId = MsgId)) =>
   Error
   <> (MsgName(Text)<:Cat0 =>
      OP0(MsgName(Text))
   <> MsgName(Text)<:Cat1 =>
      OP1(MsgName(Text))
   <> MsgName(Text)<:Cat2 =>
      OP2(MsgName(Text))
   <> MsgName(Text)<:Cat3 =>
      OP3(MsgName(Text))
   <> MsgName(Text)<:Cat4 =>
      (DeviceType(Raddr(Text)) = Printer =>
         OP4a
      <> DeviceType(Raddr(Text)) = Punch =>
         OP4b
      <> Error)
   <> MsgName(Text) = SPACE =>
      (DeviceType(Raddr(Text)) = Printer =>
         OP5
      <> Error)
   <> MsgName(Text)<:Cat5 =>
      OP6(MsgName(Text))
   <> MsgName(Text) = LOCATE-ADDR =>
      (DeviceType(Raddr(Text)) = Reader =>
         OP7a(MsgName(Text))
      <> DeviceType(Raddr(Text)) = Printer =>
         OP7b
      <> DeviceType(Raddr(Text)) = Punch =>
         OP7c
      <> DeviceType(Raddr(Text)) = TapeDrive =>
         OP7d
      <> Error)
   <> MsgName(Text) = SHUTDOWN =>
      OP8
   <> MsgName(Text) = VARY-OFFLINE =>
      (DeviceType(Raddr(Text)) = Reader =>
         OP9a
      <> DeviceType(Raddr(Text)) = Printer =>
         OP9b
      <> DeviceType(Raddr(Text)) = Punch =>
         OP9c
      <> DeviceType(Raddr(Text)) = TapeDrive =>
         OP9d
      <> Error)
   <> MsgName(Text) = VARY-ONLINE =>
      (DeviceType(Raddr(Text)) = Reader =>

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```
OP10a
<> DeviceType(Raddr(Text)) = Printer =>
OP10b
<> DeviceType(Raddr(Text)) = Punch =>
OP10c
<> DeviceType(Raddr(Text)) = TapeDrive =>
OP10d
<> Error
<> MsgName(Text) = ATTACH-RADDR =>
(DEVICE_TYPE(Raddr(Text)) = Reader =>
OP11a
<> DeviceType(Raddr(Text)) = Printer =>
OP11b
<> DeviceType(Raddr(Text)) = Punch =>
OP11c
<> DeviceType(Raddr(Text)) = TapeDrive =>
OP11d
<> Error
<> MsgName(Text) = DETACH-RADDR =>
(DEVICE_TYPE(Raddr(Text)) = Reader =>
OP12a
<> DeviceType(Raddr(Text)) = Printer =>
OP12b
<> DeviceType(Raddr(Text)) = Punch =>
OP12c
<> DeviceType(Raddr(Text)) = TapeDrive =>
OP12d
<> Error
<> MsgName(Text) = LOADBUF =>
(DEVICE_TYPE(Raddr(Text)) = Printer =>
OP13
<> Error
<> MsgName(Text) = DRAIN =>
(DEVICE_TYPE(Raddr(Text)) = Reader =>
OP14a
<> DeviceType(Raddr(Text)) = Printer =>
OP14b
<> DeviceType(Raddr(Text)) = Punch =>
OP14c
<> Error
<> MsgName(Text) = START =>
(DEVICE_TYPE(Raddr(Text)) = Reader =>
OP15a
<> DeviceType(Raddr(Text)) = Printer =>
OP15b
<> DeviceType(Raddr(Text)) = Punch =>
OP15c
<> Error
<> MsgName(Text) = TRANSFER =>
OP16
<> Error
```
transform MsgNkcp(MsgId: MessageId,
   Text: String,
   Source: ProcessName)

refcond Source<<:TrustedProcesses

effect (E"P:PendingRequest(P<:PendingRequests &
   P.MsgId = MsgId & (P.Kind = OpRequest =>
      MsgName(Text) = ResponseToOpRequest =>
         ProcessedResponse(P, MsgId, Source)
      => Error)
   => RelinquishDevice =>
      (DeviceType(Raddr(Text)) = Reader =>
         NKCP1a
      => DeviceType(Raddr(Text)) = Printer =>
         NKCP1b
      => DeviceType(Raddr(Text)) = Punch =>
         NKCP1c
      => DeviceType(Raddr(Text)) = TapeDrive =>
         NKCP1d
      => Error)
   => Error)
   => /\ message is not a response, but a request */
      (MsgName(Text) = DetachSpoolDevice =>
         (DeviceType(Raddr(Text)) = Reader =>
            PD4
         => DeviceType(Raddr(Text)) = Printer =>
            PR4
         => DeviceType(Raddr(Text)) = Punch =>
            PU4
         => Error)
   => Error)
      (MsgName(Text) = DetachDevice =>
         (DeviceType(Raddr(Text)) = Reader =>
            NKCP2a
         => DeviceType(Raddr(Text)) = Printer =>
            NKCP2b
         => DeviceType(Raddr(Text)) = Punch =>
            NKCP2c
         => DeviceType(Raddr(Text)) = TapeDrive =>
            NKCP2d
      => Error)
   => Error)
      (MsgName(Text) = NeedSpoolingDevice =>
         (DeviceType(Raddr(Text)) = Printer =>
            PR1
         => DeviceType(Raddr(Text)) = Punch =>
            PU1
      => Error)
   => Error)
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3.2.2 Unit Record Process (Formal)

transform UDRiver

InterruptType: 
InterruptSubType: 
Raddr: DeviceAddress 
Msgld: MessageId 
Text: String 
Source: ProcessName

effect (InterruptType = IOInterrupt =>
(Devicetype(Raddr) = Reader =>
RD(Raddr)
&
DeviceType(Raddr) = Printer =>
PR(Raddr)
&
DeviceType(Raddr) = Punch =>
PU(Raddr)
&
Error)
&
InterruptType = ExternalInterrupt =>
(InterruptSubType = Message =>
ReceivedMessage
&
(Source = AuthProcess =>
MsgAuth(Msgld, Text, Source)
&
Source = OpProcess =>
MsgUp(Msgld, Text, Source)
&
Source = TrustedProcesses =>
MsgNkcp(Msgld, Text, Source)
&
Error)
&
Error)
&
KernelCalled(ReceiveInterrupts)
&
KernelCalled(ReleaseCPU)
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3.2.2  Unit Record Process (Formal)  TM-6062/101/00

RD1: Unexpected IO interrupt signalling deck to be read

transform RD1(Raddr: DeviceAddress)
refcond E"R:ReaderEntry (R:<:Readers &
  R.Raddr = Raddr
  &
  R.State = Started
  &
  R.CyclePosition = Available)
  &
  ~ ShutingDown"

effect E"R:ReaderEntry(R:<:Readers & R.Raddr = Raddr &
  N"Readers = Readers ~ S"(R) ~
  S"(R,Raddr,
  R.State,
  SecurityHeader,
  R.AttachedProcess,
  R.ClassesServedCurrently,
  R.ClassesServedNextCycle,
  R.ChannelStatusWord,
  nil))
  &
  KernelCalled(RequestIO(R.Raddr)))
RD2a: Expected IO interrupt signalling security header read

```
transform RD2a(DeviceAddress, ProcessName): 
  refcond E"R:ReaderEntry (Readers & 
    R.Raddr = Raddr & 
    R.State = NotSpooling & 
    R.CyclePosition = SecurityHeader & 
    R.ChannelStatusWord.UnitCheck = false & 
    R.LineBuffer = nil)

  effect E"R:ReaderEntry (Readers & 
    R.Raddr = Raddr & 
    (E"N:NkcpEntry (N<:CurrentNkcps & 
      N.Process = Process) => 
      E"N:NkcpEntry (N<:CurrentNkcps & 
        N.Process = Process & 
        N"Readers = Readers ~/ S"(R) II 
        S"(R.Raddr,
        (A"D:DeviceAddress (D<:N.UsableReaders ~/ D = R.Raddr) 
          -(GrantedAccess) & 
          R.State = Draining => 
            Drained & 
            R.State),
        (E"D:DeviceAddress (D<:N.UsableReaders & D = R.Raddr) 
          & 
          GrantedAccess => 
            AttachedToSpoolingProcess & 
            Available),
        (E"D:DeviceAddress (D<:N.UsableReaders & D = R.Raddr) 
          & 
          GrantedAccess => 
            N.Process & 
            Available, 
        (A"D:DeviceAddress (D<:N.UsableReaders ~/ D = R.Raddr) 
          I 
          -(GrantedAccess) & 
          R.ClassesServedNextCycle 
            => R.ClassesServedCurrently), 
        R.ClassesServedNextCycle, 
        R.ClassesServedCurrently, 
        R.ChannelStatusWord, 
        R.LineBuffer) 
    & 
    R.UsableReaders & 
    R.ClassesServedNextCycle & 
    AttachedToSpoolingProcess & 
    Available & 
    R.ClassesServedCurrently & 
    R.ChannelStatusWord & 
    R.LineBuffer) 
  )
```
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3.2.2 Unit Record Process (Formal) TM-6862/101/80

(E"D;DeviceAddress(0<:N.UsableReaders & D = R.Raddr) =>
KernelCalled(GrantAccess)
&
(GrantedAccess =>
KernelCalled(SendMessage(N.Process)))
&
(R.State = Draining => KernelCalled(SendMessage(OpProcess)))
&
(R.State = Draining => KernelCalled(SendMessage(OpProcess)))
&
(R.State = Draining => KernelCalled(SendMessage(OpProcess)))
&
(R.State = Draining => KernelCalled(SendMessage(OpProcess)))
&
(R.State = Draining => KernelCalled(SendMessage(OpProcess)))
&
(R.State = Draining => KernelCalled(SendMessage(OpProcess)))
&
KernelCalled(SendMessage(AuthProcess)))}
R02b: IO Error when attempting security header read

transform R02b(Raddr: DeviceAddress)

refcond E"R:ReaderEntry (R<:Readers &
  R.Raddr = Raddr
  &
  R.State = NotSpooling
  &
  R.CyclePosition<$"(SecurityHeader, SecurityHeaderWaitForReady)
  &
  R.ChannelStatusWord.UnitCheck = true)

effect E"R:ReaderEntry(R<:Readers & R.Raddr = Raddr &
  N"Readers = Readers ~ $"(R &
  S"((R.Raddr,
    R.State,
    SecurityHeaderWaitForReady,
    R.AttachedProcess,
    R.ClassesServedCurrently,
    R.ClassesServedNextCycle,
    R.ChannelStatusWord,
    R.LineBuffer)))
  &
  KernelCalled(SendMessage(OpProcess)))
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3.2.2 Unit Record Process (Formal)

RO2c: Reader error cleared by operator (10 interrupt signalling device ready)

transform RO2c(Raddr: DeviceAddress)


& KernelCalled(RequestIO(R.Raddr))

153
RO3a: AuthProcess message re Nkcp creation: added

transform RO3a(Raddr: DeviceAddress)

refcond E"R:ReaderEntry (R<:Readers &
 R.Raddr = Raddr
 &
 E"N:NkcpEntry(N<:CurrentNkcps &
 N.Process = R.AttachedProcess))

effect E"R:ReaderEntry(R<:Readers & R.Raddr = Raddr &
 (~(R.State = NotSpooling
 &
 R.CyclePosition = AttachPending)
 => Error <=
 E"N:NkcpEntry(N<:CurrentNkcps
 &
 N.Process = R.AttachedProcess
 &
 N"Readers = Readers == S"(R) II
 S"((R.Raddr,
 /#####/   ((A"D:DeviceAddress(D<:N.UsableReaders -> D = R.Raddr)
 | ~GrantedAccess)
 &
 R.State = Draining =>
 Drained
 <> R.State),
 /#####/   (E"D:DeviceAddress(D<:N.UsableReaders & D = R.Raddr)
 &
 GrantedAccess =>
 AttachedToSpoolingProcess
 <> Available),
 /#####/   (A"D:DeviceAddress(D<:N.UsableReaders -> D = R.Raddr)
 | ~GrantedAccess =>
 URPProcess
 <> R.AttachedProcess),
 /#####/   (A"D:DeviceAddress(D<:N.UsableReaders -> D = R.Raddr)
 | ~GrantedAccess =>
 R.ClassesServedNextCycle
 <> R.ClassesServedCurrently),
 R.ClassesServedNextCycle,
 R.ChannelStatusWord,
 R.LineBuffer))

&
KernelCalled(SendMessage(N,Process))

&

(E''D:DeviceAddress(D:<N.UsableReaders & D = R.Raddr) =>
  KernelCalled(GrantAccess)
&
  ~GrantedAccess ->
  KernelCalled(SendMessage(OpProcess)))

<= KernelCalled(SendMessage(OpProcess))))
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3.2.2 Unit Record Process (Formal)

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RO3b: AuthProcess message re Nkcp creation: cannot add

transform RO3b(Raddr: DeviceAddress)

refcond E"R:ReaderEntry (R<:Readers &
R.Raddr = Raddr)

effect E"R:ReaderEntry(R<:Readers & R.Raddr = Raddr &
(~(R.State = NotSpooling
&
R.CyclePosition = AttachPending))

=> Error <>
N"Readers = Readers = S"(R) III
S"((R.Raddr,
/#&/ (R.State = Draining =>
Drained
<> R.State),
/#&/ Available,
/#&/ URProcess,
/#&/ F.ClassesServedNextCycle,
R.ClassesServedNextCycle,
R.ChannelStatusWord,
R.LineBuffer))

&
KernelCalled(SendMessage(OpProcess)))
RD4: Process releases reader after spooling

transform RD4(Raddr: DeviceAddress,
RequestingProcess: ProcessName)

refcond E*R:ReaderEntry (R<:Readers &
R.Raddr = Raddr)

effect E*R:ReaderEntry(R<:Readers & R.Raddr = Raddr &
(~(R.State = NotSpooling &
R.CyclePosition = AttachedtoSpoolingProcess &
R.AttachedProcess = RequestingProcess))
=> Error =>
N"Readers = Readers ~~ S"(R) 11
S"(R,Raddr,
/>###< (DeviceReleased & R.State = Draining =>
Drained,
/>###< (DeviceReleased =>
Available
/>###< (DeviceReleased =>
URProcess
/> R.AttachedProcess),
R.ClassesServedCurrently,
R.ClassesServedNextCycle,
R.ChannelStatusWord,
R.LineBuffer))

& KernelCalled(ReleaseDevice)
&
(R.State = Draining & ~Device Released =>
KernelCalled(SendMessage(0PProcess))
=> KernelCalled(SendMessage(R.AttachedProcess))))

163
OP14a: Drain (Reader)

transform OP14a(Raddr: DeviceAddress)

refcond E"R:ReaderEntry (R<:Readers & R.Raddr = Raddr) &
   (R.State = NotSpooling => Error <->
    N"Readers = Readers <-> S"(R) II "S"((R.Raddr,
      R.CyclePosition = Available =>
      Drained
      <-> Draining),
      R.CyclePosition,
      R.AttachedProcess,
      R.ClassesServedCurrently,
      R.ClassesServedNextCycle,
      R.ChannelStatusWord,
      R.LineBuffer)) &
   (R.CyclePosition = Available ->
    KernelCalled(SendMessage(OpProcess))))

164
OP15a: Start (Reader)

transform OP15a(Raddr: DeviceAddress, NewClasses: set of Class)

refcond E"R:ReaderEntry (R<:Readers & R.Raddr = Raddr)

effect E"R:ReaderEntry(R<:Readers & R.Raddr = Raddr & (R.State = NotSpooling
 => Error <=> N"Readers = Readers ~ S"(R) Il
 S"(R.Raddr,
 /####/ (NewClasses ~ Empty
 | R.ClassesServedCurrently ~ Empty => Started
 <=> R.State),
 R.CyclePosition, R.AttachedProcess,
 /####/ (NewClasses ~ Empty
 & R.CyclePosition = Available => NewClasses
 <=> R.ClassesServedCurrently),
 /####/ (NewClasses ~ Empty => NewClasses
 <=> R.ClassesServedNextCycle),
 R.Channel(StatusWord,
 R.LineBuffer))

& KernelCalled(SendMessage(OpProcess)))
PRI: Process request for output spooling device assignment

transform PRI(Process: ProcessName
  RequestedClasses: set of Class)

effect (A"N:NkcpEntry (N<CurrentNkcps ->
  N.Process = Process)
   
   RequestedClasses = Empty
   => Error <>

   N"PrinterSpoolRequests =
   (~ShuttingDown =>
     PrinterSpoolRequests II
   )((Process,
     RequestedClasses,
     nil,
     WaitingForDevice))
   <> PrinterSpoolRequests))
PR2: Printer Assignment (for spooling)

transform PR2(OR: OutputDeviceRequest, 
   P: PrinterEntry)

refcond DH<:PrinterSpoolRequests 
& 
P<:Printers 
& 
P.State = Started 
& 
P.CyclePosition = Available 
& 
OR.State = WaitingForDevice 
& 
ClassesMatch(P.ClassesServedCurrently, 
   ORRequestedClasses)
& 
E"N:NkcpEntry(N<:CurrentNkcps & 
   N.Process = OR.Process)

effect E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr & 
   N"Printers = Printers ~ S"(P) II 
   S"((P.Raddr, 
      P.State, 
      P.ClassesServedCurrently, 
      P.ClassesServedNextCycle, 
      P.RequestedDeviceRequestState, 
      P.ChannelStatusWord))))
& 
   N"PrinterSpoolRequests = PrinterSpoolRequests ~ S"(OR) II 
   S"((OR.Process, 
      OR.RequestedClasses, 
      OR.Device)
& 
   E"D:DeviceAddress(D<:N.UseablePrinters & D = P.Raddr) => 
      P.Raddr 
      <DR.AttachedDevice) 
& 
   E"D:DeviceAddress(D<:N.UseablePrinters & D = P.Raddr) => 
      Processing 
      <DR.State))
& 
   KernelCalled(RequestIO(P.Raddr))))
3.2.2 Unit Record Process (Formal)  

PR3a: Interrupt indicating end of security header output on printer

transform PR3a(Raddr: DeviceAddress)

refcond E"P:PrinterEntry (P<:Printers &
P.Raddr = Raddr
&
P.State == NotSpooling
&
P.CyclePosition = SecurityHeader
&
P.ChannelStatusWord.UnitCheck = false)

effect E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr &
N"Printers = Printers ∼ S"(P) &
S"(P.Raddr,
P.State,
/###/
(GrantedAccess ⇒
  AttachedToSpoolingProcess
  ⇒ SecurityTrailer),
P.AttachedProcess,
P.ClassesServedCurrently,
P.ClassesServedNextCycle,
/###/
(GrantedAccess

&
P.RelinquishDeviceRequestState = ShouldSend ⇒
Sent
⇒ P.RelinquishDeviceRequestState,
P.ChannelStatusWord))

&
(GrantedAccess ⇒
  KernelCalled(SendMessage(P.AttachedProcess))
&
(P.RelinquishDeviceRequestState = ShouldSend ⇒
  KernelCalled(SendMessage(P.AttachedProcess)))
⇒ KernelCalled(RequestIO(P.Raddr)))
PR3b: Interrupt. 10 error on attempt to output security header

transform PR3b(Raddr: DeviceAddress)
refcond E"P:PrinterEntry (P<:Printers &
   P.Raddr = Raddr
   &
   P.State = NotSpooling
   &
   P.CyclePosition<:S"(SecurityHeader,
       SecurityHeaderWaitForReady)
   &
   P.ChannelStatusWord.UnitCheck = true)

effect E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr &
   N"Printers = Printers ~> S"(P) II
   S"((P,Raddr,
       P.State,
       SecurityHeaderWaitForReady,
       P.AttachedProcess,
       P.ClassesServedCurrently,
       P.ClassesServedNextCycle,
       P.RelinquishDeviceRequestState,
       P.ChannelStatusWord))
   &
   KernelCalled(SendMessage(OpProcess)))
PR3c: Interrupt indicating OK to retry security header output

transform PR3c(Raddr: DeviceAddress)

refcond E"P:PrinterEntry (P<:Printers &
  P.Raddr = Raddr
  &
  P.State = NotSpooling
  &
  P.CyclePosition = SecurityHeaderWaitForReady
  &
  P.ChannelStatusWord.UnitCheck = false)

effect E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr &
  N"Printers = Printers ~ S"(P) II
  S"(P.Raddr,
  P.State,
  
  SecurityHeader,
  P.AttachedProcess,
  P.ClassesServedCurrently,
  P.ClassesServedNextCycle,
  P.RelinquishDeviceRequestState,
  P.ChannelStatusWord))

  &
  KernelCalled(RequestIO(P.Raddr)))
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3.2.2 Unit Record Process (Formal)

PR4: Process message, release output spooling device

transform PRPU4(Raddr: DeviceAddress, Process: ProcessName)

effect E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr &
    (~E"P:PrinterEntry (P<:Printers &
        P.Raddr = Raddr &
        P.State = NotSpooling &
        P.CyclePosition = AttachedToSpoolingProcess &
        P.AttachedProcess = Process &
        E"DR:OutputDeviceRequest(DR:<:PrinterSpoolRequests &
            DR.Process = P.AttachedProcess &
            DR.State = Processing &
            DR.AttachedDevice = P.Raddr)))
    Error <>
    N"Printers = Printers ~ S"(P) II
    S"(P.Raddr, P.State,
    /###/ SecurityTrailer,
    /###/ UIRProcess,
    P.ClassesServedCurrently,
    P.ClassesServedNextCycle,
    P.RelinquishDeviceRequestState,
    P.ChannelStatusWord))

    & E"DR:OutputDeviceRequest(DR:<:PrinterSpoolRequests &
        DR.Process = P.AttachedProcess &
        DR.State = Processing &
        DR.AttachedDevice = P.Raddr &
        N"PrinterSpoolRequests = PrinterSpoolRequests ~ S"(DR))

    & KernelCalled(RequestIO(P.Raddr)))

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PRS a: Interrupt indicating successful completion of security trailer

transform PRSa(Raddr: DeviceAddress)

recond E"P:PrinterEntry(P:Printers &
P.Raddr = Raddr
&P.State = NotSpooling
&P.CyclePosition = SecurityTrailer
&P.ChannelStatusWord.UnitCheck = false)
effect E"P:PrinterEntry(P:Printers & P.Raddr = Raddr &
N"Printers = Printers & S"(P) 11
S"{(P.Raddr,
/P#/#/ (P.State = Draining =>
Drained
<> P.State),
/P#/#/ Available,
P.AttachedProcess,
P.ClassesServedNextCycle,
P.ClassesServedNextCycle,
P.Need,
P.ChannelStatusWord))

PRSb: Interrupt, I/O error on security trailer output

transform PResb(Raddr: DeviceAddress)
refcond E"P:PrinterEntry (P<:Printers &
P.Raddr = Raddr &
P.State ~ NotSpooling &
P.CyclePosition:<S"(SecurityTrailer,
SecurityTrailerWaitForReady)
& P.ChannelStatus.Word.UnitCheck = true)
effect E"P:PrinterEntry (P<:Printers & P.Raddr = Raddr &
N"Printers = Printers ~ S"(P) ||
  S"(P.Raddr,
P.State,
/ah#s/
  SecurityTrailerWaitForReady,
P.AttachedProcess,
P.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.RelinquishDeviceRequestState,
P.ChannelStatusWord)
&
  Kernel Called (SendMessage(OpProcess)))}
PRSc: Interrupt, OK to retry security trailer output

transform PRSc(Raddr: DeviceAddress)

refcond E"P:PrinterEntry (P<:Printers &
  P.Raddr = Raddr
  &
  P.State = NotSpooling
  &
  P.CyclePosition = SecurityTrailerWaitForReady
  &
  P.ChannelStatusWord.UnitCheck = false)"

effect E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr &
  P.Raddr = Raddr &
  "Printers = Printers = S"(P) II
  S"(P.Raddr,
    P.State,
    SecurityTrailer,
    P.AttachedProcess,
    P.ClassesServedCurrently,
    P.ClassesServedNextCycle,
    P.RelinquishDeviceRequestState,
    P.ChannelStatusWord))
  &
  KernelCalled(RequestIO(P.Raddr))"

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3.2.2 Unit Record Process (Formal)  TM-682/101/00
PU1: Process request for output spooling device assignment

transform PU1(ProcessName
  RequestedClasses: set of Class)

  effect (A"N:NkcpEntry (N<:CurrentNkcpes ->
        N.Process == Process)
    | RequestedClasses = Empty
    => Error <>
    N"PunchSpoolRequests =
    (~ShuttingDown =>
      PunchSpoolRequests II
      S"((Process,
          RequestedClasses, nil,
          WaitingForDevice))")
    => PunchSpoolRequests)
**PU2**: Punch Assignment (for spooling)

**transform PU2**

```plaintext
DR: OutputDeviceRequest,
P: PunchEntry)
```

**refcond**

```plaintext
```

**effect**

```plaintext
```

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PU3a: Interrupt indicating end of security header output on punch

transform PU3a(Raddr: DeviceAddress)

refcond E"P:PunchEntry (P<:Punches &
    P.Raddr = Raddr
    &
    P.State == NotSpooling
    &
    P.CyclePosition = 'SecurityHeader
    &
    P.ChannelStatusWord.UnitCheck = false)

effect E"P:PunchEntry(P<:Punches & P.Raddr = Raddr &
    N"Puncher = Punches == $"(P) ||
    $"(P).Raddr,
    P.State,
    /##/
    (GrantedAccess =>
        AttachedToSpoolingProcess
        => SecurityTrailer),
    P.AttachedProcess,
    P.ClassesServedCurrently,
    P.ClassesServedNextCycle,
    /##/
    (GrantedAccess
    &
    P.RelinquishDeviceRequestState = ShouldSend => Sent
    => P.RelinquishDeviceRequestState),
    P.ChannelStatusWord)))

&
(GrantedAccess =>
    KernelCalled(SendMessage (P.AttachedProcess))
&
    (P.RelinquishDeviceRequestState = ShouldSend =>
        KernelCalled(SendMessage (P.AttachedProcess)))
    => KernelCalled(RequestIO(P.Raddr)))
PU3b: Interrupt. 10 error on attempt to output security header

transform PU3b(Raddr: DeviceAddress)

ref cond E"P: PunchEntry (P<: Punches &
    P.Raddr = Raddr
    &
    P.State = NotSpooling
    &
    P.CyclePosition = S"(SecurityHeader, SecurityHeaderWaitForReady)
    &
    P.ChannelStatusWord.UnitCheck = true"

effect E"P: PunchEntry (P<: Punches & P.Raddr = Raddr &
    N"Punches = Punches ~ S"(P) II
    S"(P.Raddr, P.State,
    SecurityHeaderWaitForReady, P.AttachedProcess,
    P.ClassesServedCurrently, P.ClassesServedNextCycle,
    P.RelinquishDeviceRequestState, P.ChannelStatusWord))
    &
    KernelCalled(SendMessage(OpProcess)))
PU3c: Interrupt indicating OK to retry security header output

transform PU3c(Raddr: DeviceAddress)

refcond E"P:PunchEntry (P<:Punches &
  P.Raddr = Raddr
  &
  P.State = NotSpooling
  &
  P.State = SecurityHeaderWaitForReady
  &
  P.ChannelStatusWord.UnitCheck = false)"

effect E"P:PunchEntry(P<:Punches & P.Raddr = Raddr &
  "Punches = P"''(P) II
  S''(P.Raddr,
  P.Raddr.
  P.State.
  SecurityHeader,
  P.AttachedProcess,
  P.ClassesServedCurrently,
  P.ClassesServedNextCycle,
  P.Reli queenDeviceRequestState,
  P.ChannelStatusWord))

&
  KernelCalled(RequestIO(P.Raddr))"
PU4: Process message, release output spooling device

transform PU4(Raddr: DeviceAddress,
    Process: ProcessName)

  effect E"P:PunchEntry(P:<Punches & P.Raddr = Raddr &
    (E"P:PunchEntry (P:<Punches &
      P.Raddr = Raddr
    &
    P.State = NotSpooling
    &
    P.CyclePosition = AttachedToSpoolingProcess
    &
    P.AttachedProcess = Process
    &
    E"OR:OutputDeviceRequest(OR:<PunchSpoolRequests &
      OR.Process = P.AttachedProcess
    &
      OR.State = Processing
    &
      OR.AttachedDevice = P.Raddr)))

  "Error =>
N"Punches = Punches ~ S"(P) II
S"(P.Raddr,
  P.State,
  SecurityTrailer,
  URProcess,
  P.ClassesServedCurrently,
  P.ClassesServedNextCycle,
  P.RelinquishDeviceRequestState,
  P.ChannelStatusWord)

  &
E"OR:OutputDeviceRequest(OR:<PunchSpoolRequests &
    OR.Process = P.AttachedProcess

  &
    OR.State = Processing

  &
    OR.AttachedDevice = P.Raddr

  &
N"PunchSpoolRequests =
  PunchSpoolRequests ~ S"(OR))

  &
KernelCalled(Request10(P.Raddr)))

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PUSα: Interrupt indicating successful completion of security trailer

transform PUSα(Raddr: DeviceAddress)

refcond E"P:PunchEntry(P<:Punches &
    P.Raddr = Raddr
    &
    P.State =~ NotSpooling
    &
    P.CyclePosition = SecurityTrailer
    &
    P.ChannelStatusWord.UnitCheck = false)

effect E"P:PunchEntry(P<:Punches & P.Raddr = Raddr &
    N"Punches = Punches ~ S"(P) II
    S"((P.Raddr,
    //##/1 (P.State = Draining =>
        Drained
        <= P.State),
    //##/1 Available,
    P.AttachedProcess,
    //##/1 P.ClassesServedNextCycle,
    P.ClassesServedNextCycle,
    //##/1 NoNeed,
    P.ChannelStatusWord)))
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PUSb: Interrupt, IO error on security trailer output

transform PUSb(Raddr: DeviceAddress)
refcond E"P:PunchEntry (P<:Punches &
P.Raddr = Raddr &
P.State = NotSpooling &
P.CyclePosition<1S"(SecurityTrailer,
SecurityTrailerWaitForReady) &
P.ChannelStatusWord.UnitCheck = true)

effect E"P:PunchEntry(P<:Punches & P.Raddr = Raddr &
N"Punches = Punches = S"(P) II
S"((P.Raddr,
P.State,
/##/#/ SecurityTrailerWaitForReady,
P.AttachedProcess,
P.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.RelinquishDeviceRequestState,
P.ChannelStatusWord))
&
KernelCalled(SendMessage(OpProcess)))
PUSc: Interrupt, OK to retry security trailer output

transform PUSc(Raddr: DeviceAddress)
refcond E"P:PunchEntry (P<:Punches & P.Raddr = Raddr & P.State = NotSpooling & P.CyclePosition = SecurityTrailerWaitForReady & P.ChannelStatusWord.UnitCheck = false)
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3.2.2 Unit Record Process (Formal)  TM-6862/101/00

OP14b: Drain (Printer)

transform OP14b(Raddr: DeviceAddress)

refcond E"P:PrinterEntry (Ps Printers & P.Raddr = Raddr)

effect E"P:PrinterEntry (Ps Printers & P.Raddr = Raddr &
(P.State = NotSpooling
 => Error <>
 N"Printers = Printers & S"(P) II
 S"((P.Raddr,
 /####/ (P.CyclePosition = Available =>
 Drained
 => Draining),
 P.CyclePosition,
 P.AttachedProcess,
 P.ClassesServedCurrently,
 P.ClassesServedNextCycle,
 /####/ (P.CyclePosition = AttachedToSpoolingProcess =>
 Sent
 => (P.CyclePosition = Available =>
 P.RelinquishDeviceRequestState
 => ShouldSend)),
 P.ChannelStatusWord))

&
(P.CyclePosition = Available ->
 KernelCalled(SendMessage(OpProcess)))

&
(P.CyclePosition = AttachedToSpoolingProcess
 &
 P.RelinquishDeviceRequestState <-> Sent ->
 KernelCalled(SendMessage(P.AttachedProcess))))
OP14c: Drain (Punch)

transform OP14c(Raddr: DeviceAddress)

refcond E"P:PunchEntry (P<:Punches & P.Raddr = Raddr)

effect E"P:PunchEntry(P<:Punches & P.Raddr = Raddr & (P.State = NotSpooling

=> Error <>

N"Punches = Punches ++ S"(P) II

S"(P,Raddr,

/#####/ (P.CyclePosition = Available =>

Drained

< Draining), P.CyclePosition, P.AttachedProcess, P.ClassesServedCurrently, P.ClassesServedNextCycle,

/#####/ (P.CyclePosition = AttachedToSpoolingProcess =>

Sent

< (P.CyclePosition = Available =>

P.RelinquishDeviceRequestState

< ShouldSend)),

P.Channel[StatusWord])

&

(P.CyclePosition = Available =>

KernelCalledSendMessage(OpProcess)))

&

(P.CyclePosition = AttachedToSpoolingProcess

&

P.RelinquishDeviceRequestState => Sent =>

KernelCalledSendMessage(P.AttachedProcess))))
OP15b: Start (Printer)

transform OP15b(Raddr: DeviceAddress, 
   NewClasses: set of Class)

refcond E"P:PrinterEntry (P<Printers & 
P.Raddr = Raddr)

effect E"P:PrinterEntry(P<Printers & P.Raddr = Raddr & 
   (P.State = NotSpooling 
   => Error <>
   N"Printers = Printers -- S"(P) II
   S"((P.Raddr, 
   /
   /s###/ (NewClasses == Empty
   | P.ClassesServedCurrently == Empty =>
   Started
   <= P.State),
P.CyclePosition,
P.AttachedProcess,
/s###/ (P.CyclePosition == Available
   &
   NewClasses == Empty =>)
   NewClasses
   <= P.ClassesServedCurrently).
/s###/ (NewClasses == Empty =>
   NewClasses
   <= P.ClassesServedNextCycle),
/s###/ (NewClasses == Empty =>
   (P.CyclePosition == AttachedToSpoolingProcess =>
   Sent
   <= (P.CyclePosition == Available =>
   P.RelinquishDeviceRequestState
   <= ShouldSend))
   <= P.RelinquishDeviceRequestState),
P.ChannelStatusWord))
&
KernelCalled(SendMessage(OpProcess))
&
(NewClasses == Empty &
P.CyclePosition == AttachedToSpoolingProcess
&
P.RelinquishDeviceRequestState == Sent =>
KernelCalled(SendMessage(P.AttachedProcess))))
OP15c: Start (Punch)

transform OP15c(Raddr: DeviceAddress,
NewClasses: set of Class)

refcond E"P: PunchEntry (P<:Punches &
P.Raddr = Raddr)"

effect E"P: PunchEntry (P<:Punches & P.Raddr = Raddr &
(P.State = NotSpooling => Error =>
N"Punches = Punches = S"(P) !)
S"(P.Raddr,
/###/ (NewClasses = Empty |
P.ClassesServedCurrently = Empty =>
Started
<> P.State),
P.CyclePosition,
P.AttachedProcess,
/###/ (P.CyclePosition = Available &
NewClasses = Empty =>
NewClasses
<> P.ClassesServedCurrently),
/###/ (NewClasses = Empty =>
NewClasses
<> P.ClassesServedNextCycle),
/###/ (NewClasses = Empty =>
(P.CyclePosition = AttachedToSpoolingProcess =>
Sent
<> (P.CyclePosition = Available =>
P.RelinquishDeviceRequestState
<> ShouldSend))
<> P.RelinquishDeviceRequestState),
P.Channel(StatusWord))
&
KernelCalled(SendMessage(OpProcess))
&
(NewClasses = Empty &
P.CyclePosition = AttachedToSpoolingProcess &
P.RelinquishDeviceRequestState = Sent =>
KernelCalled(SendMessage(P.AttachedProcess))))
OP0: Miscellaneous commands

commands:
QUERY=UR
QUERY=ALL
QUERY=RADOR
QUERY=TAPES

transform OP0(Command: CommandName)
refcond Command=Cat0
effect KernelCalled(SendMessage(OpProcess))
3.2.2 Unit Record Process (Formal)

OP1:
- Single message sent
- No maps
- Single response expected
- No device state information modifications

Commands:
- QUERY-READER=SPOOLID
- QUERY-PRINTER=SPOOLID
- QUERY-PUNCH=SPOOLID
- CHANGE-SYSTEM=SPOOLID

transform OP1(Command; CommandName)

refcond Command=CAT

effect N"PendingRequests = PendingRequests "
S"("NewFlagId,
   OpRequest,
   Command,
   S"("Destination(Command),
      nil,
      NoResponse))
    &
    KernelCalled(SendMessage(Destination(Command)))
OP2: Multiple messages sent
No maps
Responses expected
No device state information modifications

commands:
QUERY-FILES-ALL
QUERY-READER-ALL
QUERY-PRINTER-ALL
QUERY-PUNCH-ALL
QUERY-HOLD
CHANGE-SYSTEM-CLASS-ALL

transform OP2(Command: CommandName)
refcond Command<:Cat2
effect N"PendingRequests = PendingRequests II
S"((NewMsgId,
OpRequest,
Command,
S"R:ResponseSlot(E"N:ProcessName
(N<:CurrentNkcps &
R = (N,nil,NoResponse))))
&
A"N:ProcessName (N<:CurrentNkcps ->
KernelCalled(SendMessage(N)))"
3.2.2 Unit Record Process (Formal) TMI-6862/101/80

OP3:

Single message sent
Mapping: User id -> Nncp id
Single response expected
No device state information modifications

commands:
QUERY-FILES-USERID
QUERY-READER-USERID
QUERY-PRINTER-USERID
QUERY-PUNCH-USERID
CHANGE-USERID
FREE
HOLD
ORDER-USERID
PURGE-USERID

transform OP3(Command: CommandName)
refcond Command<:Cat3

effect N"PendingRequests = PendingRequests ||
S"((NewMsgId,
MapUserId,
Command,
S"((AuthProcess,
nil,
NoResponse)))))

&
KernelCalled(SendMessage(AuthProcess))
OP4a: commands:
  BACKSPAC
  FLUSH
  REPEAT

transform OP4a(Command::CommandName, 
                 Raddr: DeviceAddress)

refcond Command<:Cat4
  &
  E"P:PrinterEntry (P<:Printers & 
                  P.Raddr = Raddr)

effect E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr &
  ~(P.State == NotSpooling
  &
  P.CyclePosition = AttachedToSpoolingProcess)
  => Error <>
  N"PendingRequests = PendingRequests ||
  S"((NewMsgId, 
     OpRequest, 
     Command, 
     S"((P.AttachedProcess, 
        nil, 
        NoResponse)))
  &
  KernelCalled(SendMessage (P.AttachedProcess)))
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3.2.2 Unit Record Process (Formal)

OP4b: commands:
    BACKSPAC
    FLUSH
    REPEAT

transform OP4b(Command: CommandName, Raddr: DeviceAddress)

refcond Command<:Cat4
&
    E"P: PunchEntry (P<: Punches & P.Raddr = Raddr)

effect E"P: PunchEntry (P<: Punches & P.Raddr = Raddr &
    (~P.State == NotSpooling &
    & P.CyclePosition = AttachedToSpoolingProcess)
    => Error <>
    N"PendingRequests = PendingRequests 11
    S"{(NewMsgId, OpRequest, Command,
    S"{(P.AttachedProcess, nil, NoResponse))})

    KernelCalled(SendMessage(P.AttachedProcess)))

(
OP5:  command:  
SPACE

transform OP5(Command: CommandName,  
Raddr: DeviceAddress)

refcond Command = SPACE  
&  
E"P:PrinterEntry (P<:Printers &  
P.Raddr = Raddr)

effect E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr &  
&w(P.State == NotSpooling  
&  
P.CyclePosition = AttachedToSpoolingProcess)
=> Error <>  
N"PendingRequests = PendingRequests II  
S"((NewMsgId,  
OpRequest,  
Command,  
S"((P.AttachedProcess,  
nil,  
NoResponse))))  
&  
KernelCalled(SendMessage(P.AttachedProcess)))

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3.2.2 Unit Record Process (Formal)

OPS: commands:

ORDER-SYSTEM
PURGE-SYSTEM

transform OPS(Command: CommandName, Nkcps: set of ProcessName)

refcond Command<:CommandName &

A"NiProcessName(N:Nkcps ->
E"CN:NkcpEntry
(CN<:Cur.:ntNkcps &
CN.Process = N))

effect N"PendingRequests = PendingRequests ++
S"{(NewMsgId,
OpRequest,
Command,
S"Ri:ResponseSlot(E"NiProcessName
(N:Nkcps &
R = (N,nil,NilResponse)))) &

A"NiProcessName(N:Nkcps ->
KernelCalled(SendMessage(N)))

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3.2.2 Unit Record Process (Formal)

OP7a: LOCATE of Reader

transform OP7a(Command: CommandName,
Raddr: DeviceAddress)

refcond Command = LOCATE-RADDR
&
E"RI:ReaderEntry (R<:Readers &
R.Raddr = Raddr)

effect E"RI:ReaderEntry(R<:Readers & R.Raddr = Raddr &
(R.CyclePosition <=:S"(AttachedToSpoolingProcess,
AttachedToUser)

=> Error <=
N"PendingRequests = PendingRequests ll
S"((NewFlagId,
OpRequest,
Command,
S"((R.AttachedProcess,
nil,
NoResponse)))

& KernelCalled(SendMessage(D.AttachedProcess))))
OP7b:  LOCATE of Printer

transform OP7b(Command: CommandName,  
               Raddr: DeviceAddress)

refcond Command = LOCATE-RADDR  
&
   E"P:PrinterEntry (P<:Printers &  
                   P.Raddr = Raddr)

effect E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr &  
                          (P.CyclePosition AS"(AttachedToSpoolingProcess,  
                           AttachedToUser)  
                          = Error <>  
                          N"PendingRequests = PendingRequests ||  
                          S"((NewMsgId,  
                              OpRequest,  
                              Command,  
                              S"((P.AttachedProcess,  
                                  nil,  
                                  NoResponse))))  
                          &
                          KernelCalled(SendMessage(P.AttachedProcess))))
OP7c: LOCATE of Punch

transform OP7c(Command: CommandName, 
Raddr: DeviceAddress)

refcond Command = LOCATE-RADDR 
&
E"P:PunchEntry (P<:Punches & 
P.Raddr = Raddr)

effect E"P:PunchEntry (P<:Punches & P.Raddr = Raddr & 
(P:CyclePosition =<:S"(AttachedToSpoolingProcess, 
AttachedToUser)

" => Error <= 
N"PendingRequests = PendingRequests II 
S"((NewReqId, 
OpRequest, 
Command, 
S"(P.AttachedProcess, 
nil, 
NoResponse))))

& KernelCalled(SendMessage(P.AttachedProcess)))}
OP7d: LOCATE of Tape Drive

transform OP7d(Command: CommandName, 
Raddr: DeviceAddress)

refcond Command = LOCATE-RADDR

&
L"T:TapeDriveEntry (T<TapeDrives & 
T.Raddr = Raddr)

effect E"T:TapeDriveEntry(T<TapeDrives & T.Raddr = Raddr &
(T.State == AttachedToUser,
=> Error <-
N"PendingRequests = PendingRequests ||
S"((NewMagId,
OpRequest,
Command,
S"((T.AttachedProcess,
nil,
NoResponse)))))

&
KernelCalled(SendMessage(T.AttachedProcess)))
OP8: command: SHUTDOWN

transform OP8(Command: CommandName)

refcond Command = SHUTDOWN

effect N"ShuttingDown = true &
  N"PrinterSpoolRequests = PrinterSpoolRequests --
    S"DR:OutputDeviceEntry( OR.State = WaitingForDevice)
 &
  N"PunchSpoolRequests = PunchSpoolRequests --
    S"DR:OutputDeviceEntry( OR.State = WaitingForDevice)
OPSa: Vary offline (Reader)

transform OPSa(Command; CommandName, 
Raddr: DeviceAddress)

refcond Command = VARY-OFFLINE 
& 
E"R:ReaderEntry (R<Readers & 
R.Raddr = Raddr)

effect E"P:ReaderEntry (R<Readers & R.Raddr = Raddr & 
(R.CyclePosition <= S"(Available, Offline)

> Error <> 
N"Readers = Readers - S"(R) 11 
S"(R, Raddr, 
/###/ NotSpoofing, 
/###/ Offline, 
R.AttachedProcess, 
R.ClassesServedCurrently, 
R.ClassesServedNextCycle, 
R.ChannelStatusWord, 
R.LineBuffer))

& 
KernelCalled(SendMessage(OpProcess))}
OPSb: Vary offline (Printer)

transform OPSb(Command: CommandName,
    Raddr: DeviceAddress)

refcond Command = VARY-OFFLINE

    &
    E"P:PrinterEntry (Ps:Printers &
        P.Raddr = Raddr)

effect E"P:PrinterEntry(Ps:Printers & P.Raddr = Raddr &
    (P.CyclePosition <-\"Available,Offline\"))

    => Error <>
    N"Printers = Printers => S\"(P) ?

\"((P.Raddr,
    /##/ NotSpooling,
    /##/ Offline,
    P.AttachedProcess,
    P.ClassesServedCurrently,
    P.ClassesServe:NextCycle,
    P.ReinquireDeviceRequestState,
    P.Channel(StatusWord))

    &
    KernelCalled(SendMessage(OpProcess))))
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OP9c: Vary offline (Punch)

transform OP9c(Command: CommandName, Raddr: DeviceAddress)

refcond Command = VARY-OFFLINE &

E"P:PunchEntry (P<:Punches & P.Raddr = Raddr)

effect E"P:PunchEntry(P<:Punches & P.Raddr = Raddr &
(P.CyclePosition <<<S"(Available,OffLine)
=> Error <>
N"Punches = Punches <<<S"(P) II
S"((P.Raddr,
/*##*/  NotSpooling,
/*##*/  OffLine,
/*##*/  P.AttachedProcess,
P.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.RelinquishDeviceRequestState,
P.ChannelStatusWord))

&
Kernel(Called(SendMessage(OpProcess))))
OP9d: Vary offline (Tape Drive)

transform OP9d(Command: CommandName, 
                 Raddr: DeviceAddress)

refcond Command = VARY-OFFLINE
&
   E"T:TapeDriveEntry (T<TapeDrives & 
                    T.Raddr = Raddr)

effect E"T:TapeDriveEntry(T<TapeDrives & T.Raddr = Raddr & 
               (T.State <<-S"(Available,OffLine)
             => Error <>
               N"TapeDrives = TapeDrives <<-S"(T)[11
               S"(T.Raddr,
               /###/ Offline, 
               T.AttachedProcess))
 &
               KernelCalled(SendMessage(OpProcess)))
OP10a: Vary online (Reader)

transform OP10a(Command; CommandName, Raddr; DeviceAddress)
refcond Command = VARY-ONLINE &
E"R:ReaderEntry (R<:Readers & R.Raddr = Raddr)
effect E"R:ReaderEntry(R:<Readers & R.Raddr = Raddr & (~R.State = NotSpooling & R.CyclePosition = Offline)
=> Error <=
N"Readers = Readers S"(R) II
S"((R.Raddr,
/#/
Drained,
/#/
Available,
/#/
URProcess,
/#/
R.ClassesServedNextCycle,
/#/
R.ClassesServedNextCycle,
/#/
R.ChannelStatusWord,
/#/
R.LineBuffer))
&
KernelCalled(SendMessage(OpProcess))))
OP10b: Vary online (Printer)

transform OP10b(Command: CommandName,
Raddr: DeviceAddress)

refcond Command = VARY+ONLINE
&
   E*P:PrinterEntry (P<:Printers &
    P.Raddr = Raddr)

effect E*P:PrinterEntry (P<:Printers & P.Raddr = Raddr &
   (~P.State = NotSpooling
    &
    P.CyclePosition = Offline)
  => Error <>
   N"Printer = Printers " S"(P)
   S"((P.Raddr,
    P.ClassesServedNextCycle,
    P.ClassesServedNextCycle,
    NoNeed,
    P.ChannelStatusWord))
  &
  KernelCalled(SendMessage(OpProcess)))

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OP10c: Vary online (Punch)

transform OP10c(CommandName, Raddr, DeviceAddress)
refcond Command = VARY-ONLINE &
E"P:PunchEntry (P<iPunches & P.Raddr = Raddr)
effect E"P:PunchEntry (P<iPunches & P.Raddr = Raddr & ~P.State = NotSpooling & P.CyclePosition = OffLine)
   => Error <>
   N"Punches = Punches = "S"(P) II
   S"((P.Raddr,
   /##/ Drained,
   /##/ Available,
   /##/ URProcess,
   /##/ P.Class=ServedNextCycle,
   /##/ P.Class=ServedNextCycle,
   /##/ NoNeed,
   P.ChannelStatusWord))
   & KernelCalled(SendMessage(OpProcess))))
OP1@d: Vary online (Tape Drive)

transform OP1@d(Command: CommandName, Raddr: DeviceAddress)

record Command = VARY-ONLINE

 改造 Command = VARY-ONLINE

  E"T:TapeDriveEntry(T<TapeDrives & T.Raddr = Raddr)

  effect E"T:TapeDriveEntry(T<TapeDrives & T.Raddr = Raddr &
   ~T.State = OffLine)

   => Error <>
   N"TapeDrives = TapeDrives = S"T) \$
   S"(T.Raddr,
   /\##/ Available,
   /\##/ U:Process))

   & Kernel(Called(SendMessage(OpProcess))))
AUTH3a: Attach device to process (request from AuthProcess)
(Reader)

transform AUTH3a(Raddr: DeviceAddress,
Process: ProcessName)

refcond E"R:ReaderEntry (R<:Readers &
R.Raddr = Raddr)

effect E"R:ReaderEntry(R<:Readers & R.Raddr = Raddr &
(A"N: Nkcpe Entry (N<:CurrentNkcps ->
N.Process = Process)
=> Error =>
N"Readers = Readers => S"(R) II
S"(R.Raddr,
/R/ (R.State=Drained
&
R.CyclePosition=Available
&
GrantedAccess=>
NotSpooling
<= R.State),
/R/ (R.State=Drained
&
R.CyclePosition=Available
&
GrantedAccess=>
AttachedInUser
<= R.CyclePosition),
/R/ (R.State=Drained
&
R.CyclePosition=Available
&
GrantedAccess=>
Process
<= R.AttachedProcess),
R.ClassesServedCurrently,
R.ClassesServedNextCycle,
R.ChannelStatusWord,
R.LineBuffer))

&
(R.State=Drained
&
R.CyclePosition=Available =>
KernelCalled(GrantAccess(R.Raddr)))

&
KernelCalled(SendMessage(AuthProcess)))
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AUTH3b: Attach device to process (request from AuthProcess) (Printer)

transform AUTH3b (Raddr: DeviceAddress, Process: ProcessName)

refcond $P$>PrinterEntry (P$<$Printers & P.Raddr = Raddr)

effect $E$"$P$" PrinterEntry (P$<$Printers & P.Raddr = Raddr &

=> Error <=
N"Printers = Printers - $S"(P)")

S"((P.Raddr,
/"##/
(P.State=Drained
 &
P.CyclePosition=Available
 &
GrantedAccess=>
NotSpooling

=> P.State),
/"##/
(P.State=Drained
 &
P.CyclePosition=Available
 &
GrantedAccess=>
AttachedToUser

=> P.CyclePosition),
/"##/
(P.State=Drained
 &
P.CyclePosition=Available
 &
GrantedAccess=>
Process

=> P.AttachedProcess),
P.ClclassesServedCurrently,
P.ClclassesServedNextCycle,
P.RejoinishDeviceRequestState,
P.ChannelStatusWord))

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(R.State=Drained
 &
P.CyclePosition=Available=>
KernelCalled (GrantAccess (P.Raddr))

&
KernelCalled (SendMessage (AuthProcess))))
AUTH3c: Attach device to process (request from AuthProcess)
(Punch)

transform AUTH3c
(Raddr: DeviceAddress, Process: ProcessName)

refcond E"P:PunchEntry (P:<Punches &
P.Raddr = Raddr)

effect E"P:PunchEntry (P:<Punches & P.Raddr = Raddr &
A"N:NkcpEntry (N:<CurrentNkcps ->
N.Process = Process)

=> Error <>

N"Punches = Punches = S"(P) II
S"(P,Raddr,

/P#/P#/P#
(P.State=Drained
&
P.CyclePosition=Available
&
GrantedAccess=>
NotSpooling
<> P.State),

/P#/P#/P#
(P.State=Drained
&
P.CyclePosition=Available
&
GrantedAccess=>
AttachedToUser
<> P.CyclePosition),

/P#/P#/P#
(P.State=Drained
&
P.CyclePosition=Available
&
GrantedAccess=>
Process
<> P.AttachedProcess),
P.ClassesServedCurrently, P.ClassesServedNextCycle, P.RelinquishDeviceRequestState, P.Channel(StatusWord))

&
(R.State=Drained
&
P.CyclePosition=Available=>
KernelCalled (GrantAccess (P.Raddr)))

&
KernelCalled (SendMessage (AuthProcess)))
AUTH3d: Attach tape drive (request from AuthProcess)

transform AUTH3d(Raddr: DeviceAddress, Process: ProcessName, ReqAccess: AccessModes)

refcond E"T:TapeDriveEntry (T<:TapeDrives & T.Raddr = Raddr)"


=> Error <>
N"TapeDrives = TapeDrives ~ S"T) || S"(T.Raddr,
/##/ (T.State=Available
& GrantedAccess=> AttachedToUser
<> T.State),
/##/ (T.State=Available
& GrantedAccess=> Process
<> T.AttachedProcess))) &

KernelCalled(SendMessage(AuthProcess))))
OP11a: Attach device to process (request from operator) (Reader)

transform OP11a(Raddr: DeviceAddress, Process: ProcessName)

refcond E"R:ReaderEntry (R<:Readers & R.Raddr = Raddr)

effect E"R:ReaderEntry(R<:Readers & R.Raddr = Raddr &
(A"N:NkcpsEntry (N<:CurrentNkcps ->
 N.Process == Process)
 => Error <>
 N"Readers = Readers <> S"(R) II
 S"((R.Raddr, #</*#*/(R.State=Drained
 &
 R.CyclePosition=Available
 &
 GrantedAccess=>
 NotSpooling
 => R.State),
 /*#*/(R.State=Drained
 &
 R.CyclePosition=Available
 &
 GrantedAccess=>
 AttachedToUser
 => R.CyclePosition),
 /*#*/(R.State=Drained
 &
 R.CyclePosition=Available
 &
 GrantedAccess=>
 Process
 <- R.AttachedProcess),
 R.ClassesServedCurrent,  
 R.ClassesServedNextCycle,  
 R.ChannelStatusWord,  
 R.LineBuffer))
 &
 KernelCalled(SendMessage(OpProcess))
 &
 (R.State=Drained
 &
 R.CyclePosition=Available->
  (KernelCalled(GrantAccess(R.Raddr))
 &
  (GrantedAccess ->
   KernelCalled(SendMessage(Process))))))

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OP11b: Attach device to process (request from operator) (Printer)

transform OP11b(Raddr: DeviceAddress,
Process: ProcessName)

refcond E"P:PrinterEntry (P:Printers &
P.Raddr = Raddr)

effect E"P:PrinterEntry (P:Printers & P.Raddr = Raddr &
(A"N:NkcpEntry (N:CurrentNkcps ->
N.Process = Process)
  => Error <>
N"Printers = Printers - S"(P) II
S"((P.Raddr,
/###/  (P.State=Dreained
  &
P.CyclePosition=Available
  &
GrantedAccess=>
  NotSpooling
  <> P.State),
/###/  (P.State=Dreained
  &
P.CyclePosition=Available
  &
GrantedAccess=>
  AttachedToUser
  <> P.CyclePosition),
/###/  (P.State=Dreained
  &
P.CyclePosition=Available
  &
GrantedAccess=>
  Process
  <> P.AttachedProcess),
P.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.RelinquishDeviceRequestState,
P.ChannelStatusWord))

&
KernelCalled(SendMessage(OpProcess))

&
(P.State=Dreained
  &
P.CyclePosition=Available->
  (KernelCalled(GrantAccess(P.Raddr))
  &
  (GrantedAccess ->
  KernelCalled(SendMessage(Process))))))))

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OP11c: Attach device to process (request from operator) (Punch)

transform OP11c(Raddr: DeviceAddress, Process: ProcessName)

refcond E”P:PunchEntry (P:Punches & P.Raddr = Raddr)

<= Error <-
N”Punches = Punches = S”(P) II
S”((P.Raddr, /n##/ (P.State=Drained
 & P.CyclePosition=Available
 & GrantedAccess=)
 NotSpooling
 <= P.State),
 /n##/ (P.State=Drained
 & P.CyclePosition=Available
 & GrantedAccess=)
 AttachedToUser
 <= P.CyclePosition),
 /n##/ (P.State=Drained
 & P.CyclePosition=Available
 & GrantedAccess=)
 Process
 <= P.AttachedProcess),
P ClassesServedCurrently, P.ClassesServedNextCycle, P.RelinquishDeviceRequestState, P.ChannelStatusWord))
 & KernelCalled(SendMessage(OpProcess))
 & (P.State=Drained
 & P.CyclePosition=Available->
 (KernelCalled(GrantAccess(P.Raddr))
 & (GrantedAccess=->
 KernelCalled(SendMessage(Process)))))))

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3.2.2 Unit Record Process (Formal)

OP12a: Detach dedicated device from user (request from operator) (Reader)

transform OP12a(Raddr, DeviceAddress, Process: ProcessName)

refcond E'R: ReaderEntry (R< Readers & R.Raddr = Raddr)

effect E'R: ReaderEntry (R< Readers & R.Raddr = Raddr &
~(R.State = NotSpooling &
R.CyclePosition = AttachedToUser &
R.AttachedProcess = Process)
=> Error <> N"Readers = Readers ~ S"(R)
S"(R.Raddr, R.State, /n###/ DetachPending, R.AttachedProcess, R.ClassesServedCurrently, R.ClassesServedNextCycle, R.ChannelStatusWord, R.LineBuffer)
& N"PendingRequests = PendingRequests ~ S"(NewMsgId,
RelinquishDevice,
Undefined,
S"(R.AttachedProcess, nil, NoResponse))))

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OP12b: Detach dedicated device from user (request from operator)

(Printer)

transform OP12b(Raddr: DeviceAddress,
    Process: ProcessName)

refcond E"P:PrinterEntry (P<:Printers &
    P.Raddr = Raddr)

effect E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr &
    (~P.State = NotSpooling
      &
      P.CyclePosition = AttachedToUser
      &
      P.AttachedProcess = Process)

  => Error <=

  N"Printers = Printers ~ S"(P) II

S"((P.Raddr,

    P.State,

    DetachPending,
    P.AttachedProcess,
    P.ClassesServedCurrently,
    P.ClassesServedNextCycle,
    P.RelinquishDeviceRequestState,
    P.ChannelStatusWord))

&

N"PendingRequests = PendingRequests II

S"((NewMsgId,

    RelinquishDevice,
    Undefined,

    S"((P.AttachedProcess,

    nil,

    NoResponse)))))))
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3.2.2 Unit Record Process (Formal) TM-6862/181/88

OP12c: Detach dedicated device from user (request from operator)
(Punch)

transform OP12c(Raddr: DeviceAddress,
Process: ProcessName)

refcond E"P:PunchEntry (P<:Punches &
P.Raddr = Raddr)"

effect E"P:PunchEntry(P<:Punches & P.Raddr = Raddr &
~(P.State = NotSpooling
&
P.CyclePosition = AttachedToUser
&
P.AttachedProcess = Process)
=> Error <>
N"Punches = Punches ~ S"(P) II
S"(P.Raddr,
P.State,
AttachPending,
P.AttachedProcess,
P.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.RelinquishDeviceRequestState,
P.ChannelStatusWord))
&
N"PendingRequests = PendingRequests II
S"((NewTagId,
RelinquishDevice,
Undefined,
S"((P.AttachedProcess,
nil,
NoResponse))))

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NKCP2a: Detach dedicated device from user (request from attached process) (Reader)

transform NKCP2a(Raddr: DeviceAddress, Process: ProcessName)

refcond E"R: ReaderEntry (R<:Readers & R.Raddr = Raddr)

effect E"R: ReaderEntry(R<:Readers & R.Raddr = Raddr &
(¬(R.State = NotSpooling &
 & R.CyclePosition = AttachedToUser &
 & R.AttachedProcess = Process)
 => Error 0)
 N"Readers = Readers - S"(R) 11
 $"(R.Raddr, /"#/"/ (DeviceReleased->
 Drained
 => R.State),
 /"#/"/ (DeviceReleased->
 Available
 => R.CyclePosition),
 /"#/"/ (DeviceReleased->
 URProcess
 => R.AttachedProcess),
 R.ClassesServedCurrently,
 R.ClassesServedNextCycle,
 R.ChannelStatusWord,
 R.LineBuffer))
 & KernelCalled(ReleaseDevice(R.Raddr))
 & KernelCalled(SendMessage(R.AttachedProcess))
 & KernelCalled(SendMessage(OpProcess))))
NKCP2b: Detach dedicated device from user (request from attached process) (Printer)

transform NKCP2b(Raddr: DeviceAddress, Process: ProcessName)

refcond E"P:PrinterEntry (P:Printers & P:Raddr = Raddr)

effect E"P:PrinterEntry(P:Printers & P:Raddr = Raddr &
& P:CyclePosition = AttachedToUser
& P:AttachedProcess = Process)

=> Error <>
N"Printers = Printers <> S"(P) II
S"((P:Raddr,
"#"/ (DeviceReleased ->
Drained
<> P:State),
"#"/ (DeviceReleased ->
Available
<> P:CyclePosition),
"#"/ (DeviceReleased ->
URProcess
<> P:AttachedProcess),
P:ClassesServedCurrently,
P:ClassesServedNextCycle,
P:RelinquishDeviceRequestState,
P:ChannelStatusWord))
& KernelCalled(ReleaseDevice(P:Raddr))
& KernelCalled(SendMessage(P:AttachedProcess))
& KernelCalled(SendMessage(OpProcess)))
NKCP2c: Detach dedicated device from user (request from attached process) (Punch)

transform NKCP2c(Raddr: DeviceAddress, Process: ProcessName)

refcond E"P:PunchEntry (P<Punches &
P.Raddr = Raddr)"

effect E"P:PunchEntry(P<Punches &
P.Raddr = Raddr &
~(P.State = NotSpooling
&
P.CyclePosition = AttachedToUser
&
P.AttachedProcess = Process)
-> Error <>
N"Punches = Punches ~ S"(P) II
S"(P.Raddr,
/##/ (DeviceReleased=>
  Drained
  <> P.State),
/##/ (DeviceReleased=>
  Available
  <> P.CyclePosition),
/##/ (DeviceReleased=>
  URProcess
  <> P.AttachedProcess),
P.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.RelinquishDeviceRequestState,
P.ChannelStateWord))
&
KernelCalled(ReleaseDevice(P.Raddr))
&
KernelCalled(SendMessage(P.AttachedProcess))
&
KernelCalled(SendMessage((upProcess))))
OP12d: Detach dedicated device from user (request from operator) (Tape Drive)

transform OP12d(Raddr: DeviceAddress, Process: ProcessName)

refcond E"T: TapeDriveEntry(T<:TapeDrives & T.Raddr = Raddr)

effect E"T: TapeDriveEntry(T<:TapeDrives & T.Raddr = Raddr &

(T.State=Attached &

 T.AttachedProcess=Process)

 => Error <>

"Tapes = TapeDrives <> S"(T) II
S"(T.Raddr,"
##/ DetachPending,
T.AttachedProcess))

"PendingRequests = PendingRequests II
S"(NewRequestId,
RelinquishDevice,
Undefined,
S"(T.AttachedProcess, nil, NoResponse))))}
NKCP2d: Detach dedicated device from user (request from attached process) (Tape Drive)

transform NKCP2d(Raddr: DeviceAddress,
Process: ProcessName)

refcond E"T:TapeDriveEntry(T<TapeDrives &
T.Raddr = Raddr)

effect E"T:TapeDriveEntry(T<TapeDrives & T.Raddr = Raddr &
~(T.State = Attached
&
T.AttachedProcess = Process)
=> Error <>
N"TapeDrives = TapeDrives && S"(T) II
S"(T.Raddr,
stmt
(DeviceReleased=>
Available
<> T.State),
stmt
(DeviceReleased=>
URProcess
<> T.AttachedProcess)))
&
KernelCalled(ReleaseDevice(T.Raddr))
&
KernelCalled(SendMessage(T.AttachedProcess))
&
KernelCalled(SendMessage(0pProcess))))
NKCP1a: Process message, relinquishing device as requested (Reader)

transform NKCP1a(Raddr;DeviceAddress, Process;ProcessName)

recond E"R:ReaderEntry (R<:Readers & R.Raddr = Raddr)

effect E"R:ReaderEntry(R<:Readers & R.Raddr = Raddr &
  1= (R.State = NotSpoofing &
  & R.CyclePosition = DetachPending &
  & R.AttachedProcess = Process)
  => Error <>
  N"Readers = Readers ~ s"(R) I1
  s"(R.Raddr, /###/ (DeviceReleased=>
  Drained
  <> R.State), /###/ (DeviceReleased=>
  Available
  <> R.CyclePosition), /###/ (DeviceReleased=>
  (RPProcess
  <> R.AttachedProcess),
  R.ClassesServedCurrently, R.ClassesServedNextCycle,
  R.ChannelStatusWord,
  R.LineBuffer)) &
  KernelCalled!ReleaseDevice(R.Raddr)
  &
  KernelCalled(SendMessage(R.AttachedProcess)) &
  KernelCalled(SendMessage(0pProcess))))
NKCP1b: Process message, relinquishing device as requested (Printer)

transform NKCP1b(Raddr:DeviceAddress, Process:ProcessName)

refcond E"P:PrinterEntry (P<:Printers & P.Raddr = Raddr)


N"Printers = Printers ~ ~ S"(P) II S"((P.Raddr,
/###/ (DeviceReleased=> Drained => P.State),
/###/ (DeviceReleased=> Available => P.CyclePosition),
/###/ (DeviceReleased=> UPRProcess => P.AttachedProcess),
P.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.RelinquishDeviceRequestState,
P.ChannelStatusWord))

& KernelCalled(ReleaseDevice(P.Raddr))
& KernelCalled(SendMessage(P.AttachedProcess))
& KernelCalled(SendMessage(OpProcess)))
NKCP1c: Process message, relinquishing device as requested
(Punch)

transform NKCP1c(Raddr:DeviceAddress,
Process:ProcessName).

refcond E"P:PunchEntry (P<:Punches &
P.Raddr = Raddr)

effect E"P:PunchEntry(P<:Punches & P.Raddr = Raddr &
(P.State = NotSpooling
 &
P.CyclePosition = DetachPending
 &
P.AttachedProcess = Process)

=> Error <=
N"Punches = Punches ~ S"(P) II
S"((P.Raddr,
/##/ (DeviceReleased=>
Drained
<= P.State),
/##/ (DeviceReleased=>
Available
<= P.CyclePosition),
/##/ (DeviceReleased=>
URProcess
<= P.AttachedProcess),
P.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.RelinquishDeviceRequestState,
P.ChannelStatusWord))

&
KernelCalled(ReleaseDevice(P.Raddr))
&
KernelCalled(SendMessage(P.AttachedProcess))
&
KernelCalled(SendMessage(OpProcess)))

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OP13: Loadbuf

transform OP13(Raddr: DeviceAddress)
refcond E"P:PrinterEntry (P<:Printers &
          P.Raddr = Raddr)

effect E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr &
                 \(\sim(P, State = Drained \\
                 \&
                 P, CyclePosition = Available) \\
                 \Rightarrow Error \leftarrow \\
                 \Rightarrow true))"
NKCPId: Process message, relinquishing device as requested (Tape Drive)

transform NKCPId(Raddr: DeviceAddress, Process: ProcessName)

refcond E"T: TapeDriveEntry (T<TapeDrives & T.Raddr = Raddr)
effect E"T: TapeDriveEntry(T<TapeDrives & T.Raddr = Raddr &
~(T.State = DetachPending
&
T.AttachedProcess = Process)
=> Error <>
N"TapeDrives = TapeDrives" == S"(T) II
S"(T.Raddr,
/####/ (DeviceReleased =>
Available
< T.State)
/####/ (DeviceReleased =>
URProcess
<= T.AttachedProcess))
&
KernelCalled(ReleaseDevice(T.Raddr))
&
KernelCalled(SendMessage(T.AttachedProcess))
&
KernelCalled(SendMessage(OpProcess)))
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3.2.2 Unit Record Process (Formal)  TH-5862/101/88

OP11d: Attach tape drive (request from operator)

transform OP11d(Raddr: DeviceAddress,
    ReqAccess: AccessModes,
    TapeSecLevel: ProcessName,
    Process: ProcessName)

refcond E"T:\TapeDriveEntry (T<:TapeDrives &
   T.Raddr = Raddr)

effect E"T:\TapeDriveEntry(T<:TapeDrives & T.Raddr = Raddr &
   (A"N:WorkEntry (N<:CurrentNkps =>
      N.Process => Process)
   => Error =>
      E"N:\WorkEntry(N<:CurrentNkps &
         N.Process=Process
     &
         N"TapeDrives = TapeDrives => S"(T) ||
         S"((T.Raddr,
            /a##/ (T.Raddr<:N.UsableTapeDrives
            &
            T.State=Available
            &
            CheckedSecLevel
            &
            GrantedAccess=>
               Attached
            <=> T.State),
            /a##/ (T.Raddr<:N.UsableTapeDrives
            &
            T.State=Available
            &
            CheckedSecLevel
            &
            GrantedAccess=>
               N.Process
            <=> T.AttachedProcess)))

&
KernelCalled(SendMessage(OpProcess)) & (T.Raddr:N.UsableTapeDrives & T.State = Available) -> (KernelCalled(CheckSecLevel)) & (CheckedSecLevel -> (KernelCalled(GrantAccess(T.Raddr)) & (GrantedAccess -> KernelCalled(SendMessage(N.Process))))))}
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3.2.2 Unit Record Process (Formal)

AUTH1: Add Nkcp

transform AUTH1(Process: ProcessName
Readers: set of DeviceAddress,
Printers: set of DeviceAddress,
Punches: set of DeviceAddress,
TapeDrives: set of DeviceAddress)

refcond true

effect (E"N:NkcpEntry (N<CurrentNkcps &
N.Process = Process)
=> Error <=
N"CurrentNkcps = CurrentNkcps ||
S"((Process,
Readers,
Printers,
Punches,
TapeDrives)))

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AUTH2: Delete Nkcp

transform AUTH2(Process: ProcessName)
effect (AUTH2: NkcpEntry (N<:CurrentNkcps -> N.Process == Process) =>
  E"DR:OutputDeviceRequest
    ((OR<:PrinterSpoolRequests
      &
      OR<:PunchSpoolRequests
    &
    OR.Process = Process
    &
    OR.State = Processing)
  &
  E"R:ReaderEntry (R<:Readers &
    R.AttachedProcess = Process
    &
    R.CyclePosition<:"(AttachedToSpoolingProcess,AttachedToUser))
  &
  E"P:PrinterEntry (P<:Printers &
    P.AttachedProcess = Process
    &
    P.CyclePosition<:"(AttachedToSpoolingProcess,AttachedToUser))
  &
  E"P:PunchEntry (P<:Punches &
    P.AttachedProcess = Process
    &
    P.CyclePosition<:"(AttachedToSpoolingProcess,AttachedToUser))
  &
  E"T:TapeDriveEntry (T<:TapeDrives &
    T.AttachedProcess = Process
    &
    T.State = AttachedToUser)
    Error =>
    E"N:NkcpEntry (N<:CurrentNkcps & N.Process == Process &
    N"CurrentNkcps = CurrentNkcps =="(N)
    &
    N"PrinterSpoolRequests = PrinterSpoolRequests --
    S"DR:OutputDeviceEntry
      (OR<:PrinterSpoolRequests
      &
      OR.AttachedProcess = N.Process)
    &
    N"PunchSpoolRequests = PunchSpoolRequests --
    S"DR:OutputDeviceEntry
      (OR<:PunchSpoolRequests
      &
      OR.AttachedProcess = N.Process)))

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3.2.2 Unit Record Process (Formal) TH-6062/101/00

KERN: message from Kernel, re device availability (during scan
at system initialization)

transform KERN(Raddr: DeviceAddress)

effect (E"R:ReaderEntry(R<:Readers & R.Raddr = Raddr) =>
E"R:ReaderEntry(R<:Readers & R.Raddr = Raddr &
(R.State = Drained =>
N"Readers = Readers => S"(R) II
S"((R.Raddr,)
/*#*/ NotAvailableForSpooling
/*#*/ Offline,
R.AttachedProcess,
R.ClassesServedCurrently,
R.ClassesServedNextCycle,
R.ChannelStatusWord,
R.LineBuffer))
<> Error))
<> E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr) =>
E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr &
(P.State = Drained =>
N"Printers = Printers => S"(P) II
S"((P.Raddr,
/*#*/ NotAvailableForSpooling,
/*#*/ Offline,
P.AttachedProcess,
P.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.ReinmediateDeviceRequestState,
P.ChannelStatusWord))
<> Error))
<> E"P:PunchEntry(P<:Punches & P.Raddr = Raddr) =>
E"P:PunchEntry(P<:Punches & P.Raddr = Raddr &
(P.State = Drained =>
N"Punches = Punches => S"(P) II
S"((P.Raddr,
/*#*/ NotAvailableForSpooling,
/*#*/ Offline,
P.AttachedProcess,
P.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.ReinmediateDeviceRequestState,
P.ChannelStatusWord))
<> Error))
<> E"T:TapeDriveEntry(T<:TapeDrives & T.Raddr = Raddr) =>
E"T:TapeDriveEntry(T<:TapeDrives & T.Raddr = Raddr &
(T.State = Available =>
N"TapeDrives = TapeDrives => S"(T) II
S"((T.Raddr,
/*#*/ Offline,
T.AttachedProcess))
<> Error)))

end URProcess

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3.3.1 Authorization Process
Informal Description

This section contains the informal description of the Authorization Process of KVM/378.

Overview

The Authorization Process performs several functions of major importance to the system security of KVM/378. The Authorization Process acts as the security policeman of the system by controlling accessibility to the machine via the logon/off protocols, and by helping the Kernel keep the system in a set of security-preserving states by controlling non-unit record device attachment for all system processes. It also examines the security conditions surrounding all device attachments (for both unit record and non-unit record devices) to NKCPs.

The Authorization Process performs the following major functions:

- logon sequence;
- logoff sequence;
- links;
- non-unit record device attachment for all other system processes;
- security condition assurance for all device attachments; and
- NKCP creation and deletion.

The Authorization Process monitors the status of all non-unit record devices in its device tables. It uses a data structure called the 'directory' to control both user access to the system and the processing of links.

Figures four and five display the organization of the transforms involved in the logon protocol. Figure six displays the various states in which a particular line can exist, and the legal transitions between states.
Figure 4

THE ATTACH VALIDATION SEQUENCE
(PROCESS STRUCTURE)
3.3.1 Authorization Process (Informal)

INITIAL LOGON
STATE = AVAILABLE

RETRY
STATE = RETRY

LGDL1

STATE = READ INITIAL PASSWORD

LGDL2

STATE = READ ACCESS PASSWORD

LGDL3

STATE = PERFORM RESOURCE CHECKS

LGDL4

STATE = HOOKING PERIPHERALS

LGDL5

STATE = NOTIFYING Nkop

LGDL6

STATE = NOTIFYING Kop

LGDL7

STATE = ATTACHED

LGDL8

Figure 5
The Attach Validation Sequence
(State Transitions)
3.3.1 Authorization Process (Informal)

Figure 6
The Line Activity Cycle
The Logon Sequence

When the user presses the 'break' key after dialing into the system, the resulting interrupt is reflected by the semi-trusted process monitoring all input lines to the Authorization Process, which then requests a 'read' on the line. The user then types the logon information, consisting of at least a header string, a user id, a password, and a security level. The Authorization Process uses this information and the directory information associated with this user to determine whether the attempted logon will be allowed. The factors involved in this decision include:

- the user's security level provided in the logon line;
- the communication line's security level;
- the security levels associated with the user in the user's directory entry; and
- whether an NKCP controlling the requested security level currently exists in the system, the number of NKCPs currently extant, and the maximum allowable number.

The Authorization Process must perform a fair amount of processing in order to determine whether the user is allowed to log on given the current state of the system and the requested security level.

Assuming the logon decision is affirmative, the Authorization Process uses the 'dedicated devices' section of the directory entry for this user to determine those devices that must be attached to (the controlling NKCP for) the new VM in order for the VM to perform. The Authorization Process attaches the permissible devices (pursuant to security conditions and the requested security level), the communication line and the new VM to the NKCP controlling this security level. These attachments all occur after first creating the NKCP if necessary and possible.

It then notifies the controlling NKCP of the existence of the new VM. Part of the message sent to the NKCP contains non-security-relevant directory information about the VM, in particular information about the VM's attached devices.
The Logoff Sequence

When a VM is to be purged from the system, the NKCP releases all the devices dedicated to the VM, performs accounting, and then informs the Authorization Process. It also provides the reason for the purge, which could be because the user logged off, or because the NKCP forced the user off (due to operator requests FORCE or SHUTDOWN), or because the user was disconnected and at least fifteen minutes have elapsed, etc.

The Authorization Process proceeds to destroy the VM and, if necessary, causes the communication line to be re-enabled for a new user connection.

If the Kernel does not allow the VM to be destroyed, the Authorization Process informs the NKCP of this fact.
NKCP Creation and Deletion

An NKCP is added to the system when an attempt is made to perform processing at a security level not currently being provided by the system. This request for support of a new security level may be caused by a user logging on or by an input spooling operation.

The Authorization Process attempts to create the NKCP to service the new security level. If it succeeds, the new user is attached in the normal manner or, in the case of an input spooling operation, the Unit Record Process is informed of the availability of the new NKCP so that it may attach the input device to the NKCP.

Due to limitations of Kernel table space or system performance requirements, creation of the new NKCP may not be possible. In this case the user's logon attempt is rejected or the input spooling operation is aborted.

It may also be the case that an NKCP has been created and the reason for its existence has disappeared. This will occur if the user does not complete the logon, the attempt to create a VM fails due to lack of table space, the input device becomes disabled or, in the case of an input spooling operation, the NKCP may not use the input device due to security conditions. The Authorization Process (or in the case of an input spooling operation, the Unit Record Process) will inform the NKCP that it is not needed. However, due to the inherent asynchronicity of the system, the NKCP may have become useful by one trusted process even as another was deciding it was not really needed. Thus the message to the NKCP should be interpreted as "Perhaps if you have no work to do, you may purge yourself," rather than an imperative command, "Purge yourself!" It is up to the NKCP to make the request of the Authorization Process which causes the actual purge of the NKCP.

Any time an NKCP discovers that it has no work to do (i.e., it has completed all of its tasks and nothing remains), it should request that it be purged from the system, by sending a message to the Authorization Process. The Authorization Process attempts to purge the NKCP. If the NKCP cannot be purged, the Authorization Process returns a message to the NKCP, which should then abort.
Operator Process
- Requests -

AUTOLOG
QUERY
DASD -
LINES -
GRAF -
SYSTEM -
NAMES -
USERY -
user id -
raddr - [raddr must be non-unit record device]
ALL -

SHUTDOWN
ATTACH raddr - [raddr must be non-unit record device]
DETACH raddr - [raddr must be non-unit record device]
VARY raddr - [raddr must be non-unit record device]
LOCATE raddr - [raddr must be non-unit record device]
MapUserId
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3.3.1 Authorization Process (Informal) TM-6062/181/88

Unit Record Process
- Requests -

NeedNkcp
MapUserId

Unit Record Process
- Responses -

URDeviceAttached
URDeviceNotAvailable

NKCP Requests

Logoff
Disconnect
Detach raddr - [raddr must be non-unit record device]
DestroyMe

NKCP Responses

ResponseToOpRequest
module AuthProcess

type
DeviceAddress,
LineAddress,
ProcessName,
VirtMachineName,
Volumelne,

CommandName = (AUTOLOG, ATTACH-RADDR, DETACH-RADDR, VARY-ONLINE,
VARY-OFFLINE, QUERY-DASQ, QUERY-LINES, QUERY-GRAF,
QUERY-NAMES, QUERY-USERS-X, QUERY-ALL, QUERY-SYSTEM-RADDR,
QUERY-RADDR, QUERY-USERS-USERID, QUERY-USERID,
LOCATE-RADDR, SHUTDOWN),

Cat6a = T"(QUERY-DASQ, QUERY-LINES, QUERY-GRAF, QUERY-NAMES,
QUERY-USERS-X, QUERY-ALL),

Cat6b = T"(QUERY-SYSTEM-RADDR, QUERY-RADDR),

Cat6c = T"(QUERY-USERS-USERID, QUERY-USERID),

MessageNames

constant
Dominates(ProcessName, ProcessName): boolean,
DeviceType(DeviceAddress): DeviceTypes,
#Cylinders(Volumelne): T"integer(0<1),
Raddr(String): DeviceAddress,
Laddr(String): DeviceAddress,
MsgName(String): MessageNames,

constant
AddressSpaceSize: T"integer(0<1 & 1<8191)
CodeSize: T"integer(0<1 & 1<8191),
Code: integer,
#MaxCylinders: T"integer(1>0),
#MaxRetries: T"integer(1>0),
#MaxNkcs: T"integer(1>0),
#MaxVMes: T"integer(1>0)
type
RequestCategory = (Attach, ClearLine, RedirectLine, WriteAndReadLine,
Delete, NewVM, ConnectVM, NewUser,
NewOrConnectedVM, ReUtilizeDevice),

ResponseStatus = (NoResponse, Responded),
AccessModes = (Read, Write),

LineStatus = (Retry, Disabled, Available, ReadInitialPassword,
ReadAccessPassword, PerformResourceChecks, HookingPeripherals,
NotifyingNkcp, Attached, ReadLinkPassword, ReEnablePending),

ShareableDriveStatus = (Offline, Available, AttachedToSystem),
DriveStatus = (Offline, DetachPending, AttachedToUser, Available),
VolumeStatus = (Mounted, NotMounted),
LinkAccess = (R, RR, W, WR, M, MR, NW),
LineCondition = T"(Disabled, Available),
ActivityStatus = (Free, Attached, AttachValidation),
AccessCategory = (Logon, Dial),
ReasonTypes = (IncorrectLogon, ResourceFailure, SecurityViolation,
MaxThresholdExceeded, NoNkcp, NoYN, TerminalClearanceMismatch),

LogoffReasons = (UserChoice, Forced, Disconnected),

DirectoryEntry = structure of {
  UserId = VirtualMachineName,
  LogonPassword = String,
  DialPassword = String,
  LinkPassword = String,
  MaxSecLevel = ProcessName,
  MinSecLevel = ProcessName,
  DedicatedDevices = set of DedicatedDeviceEntry,
  Links = set of MDLinkEntry,
  [p]Defined = boolean,
  AccessPasswords = set of AccessPasswordEntry),

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LineEntry = structure of ( 
    Laddr = LineAddress, 
    MaxSecLevel = ProcessName, 
    MinSecLevel = ProcessName, 
    State = ActivityStatus, 
    CyclePosition = LineStatus, 
    RequestedSecLevel = ProcessName, 
    AttachedVM = VirtualMachineName, 
    Connection = AccessCategory, 
    LineDropped = boolean, 
    #Retries = 0..#MaxRetries, 
    #AwaitingHooks = nonnegative integer, 
    Msg = String),

NkcpEntry = structure of ( 
    Process = ProcessName, 
    VMs = set of VMEntry, 
    AttachedDevices = set of AttachedDeviceEntry, 
    Links = set of MDLinkEntry),

AccessPasswordEntry = structure of ( 
    SecLevel = ProcessName, 
    Password = String),

VMEntry = structure of ( 
    VMName = VirtualMachineName, 
    Laddr = LineAddress, 
    Disconnected = boolean, 
    Users = set of LineAddress),

DedicatedDeviceEntry = structure of ( 
    Raddr = DeviceAddress, 
    VolSecLevel = ProcessName, 
    Access = set of AccessModes),

AttachedDeviceEntry = structure of ( 
    Raddr = DeviceAddress, 
    Access = set of AccessModes),

MDLinkEntry = structure of ( 
    MDName = MiniDiskName, 
    Access = set of AccessModes),

ProcessLinkEntry = structure of ( 
    Process = ProcessName, 
    Access = set of AccessModes),

URPOwnedDeviceEntry = structure of ( 
    Raddr = DeviceAddress, 
    MaxSecLevel = ProcessName, 
    MinSecLevel = ProcessName),

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NonshareableDriveEntry = structure of (  
  Raddr = DeviceAddress,  
  MaxSecLevel = ProcessName,  
  MinSecLevel = ProcessName,  
  State = DriveStatus,  
  AttachedProcess = ProcessName,  
  Access = set of AccessModes),

ShareableDriveEntry = structure of (  
  Raddr = DeviceAddress,  
  State = ShareableDriveStatus,  
  SecLevel = ProcessName,  
  MountedVolume = VolumeId),

SharedVolumeEntry = structure of (  
  Volume = VolumeId,  
  SecLevel = ProcessName,  
  MountedDevice = DeviceAddress,  
  State = VolumeStatus),

MiniDiskEntry = structure of (  
  MDName = MiniDiskName,  
  ContainingVolume = VolumeId,  
  Cylinders = \( \sum_{i=1}^{\text{MaxCylinders}} \) \( \{ i \leq \text{MinCylinders} \} \cup \{ i \geq \text{MaxCylinders} \} \),  
  SecLevel = ProcessName,  
  CurrentLinks = set of ProcessLinkEntry,  
  AccessControlList = set of ACLEntry),

ACLEntry = structure of (  
  User = VirtualMachineName,  
  Access = set of AccessModes),

ResponseSlot = structure of (  
  Respondent = ProcessName,  
  Text = String,  
  Status = ResponseStatus),

PendingRequest = structure of (  
  MsgId = MessageId,  
  Kind = RequestCategory,  
  Command = CommandName,  
  Responses = set of ResponseSlot)
variable
Nkcp: NkcpRange,
VM: VMRange,
User: UserRange,
Shutting Down: boolean,
URPOwnedDevices: set of URPOwnedDeviceEntry,
NonsharableDrives: set of NonsharableDriveEntry,
SharableDrives: set of SharableDriveEntry,
SharedVolumes: set of SharedVolumeEntry,
Minidisks: set of MinidiskEntry,
CurrentNkcps: set of NkcpEntry,
Lines: set of LineEntry,
UserDirectory: set of DirectoryEntry,
PendingRequests: set of PendingRequest
initial
#Nkcses = 0
&
#VMs = 0
&
#Users = 0
&
(~ShuttingDown)
&
A"NS:NonsharableDriveEntry(NS:<NonsharableDrives ->
    NS.State = Available
    &
    NS.AttachedProcess = AuthProcess
&
A"S:SharableDriveEntry(S:<SharableDrives ->
    S.State = Available)
&
A"V:SharedVolumeEntry(V:<SharedVolumes ->
    V.State = NotMounted)
&
A"M:MiniDiskEntry(M:<MiniDisks ->
    M.CurrentLinks = Empty)
&
CurrentNkcps = Empty
&
A"L:LineEntry(L:<Lines ->
    L.State = Free
    &
    L.CyclePosition = Available
    &
    L.AttachedVM = AuthProcess)
&
PendingRequests = Empty
3.3.2 Authorization Process (Formal)

```
invariant
#Nkcpe <= #MaxNkcpe
&
#VMs <= #MaxVMs
&
#Users <= #MaxUsers
&
InvariantsOfURPOwnedDevices
&
InvariantsOfNonshareableDrives
&
InvariantsOfShareableDrives
&
InvariantsOfSharedVolumes
&
InvariantsOfMiniDisks
&
InvariantsOfCurrentNkcpe
&
InvariantsOfLines
&
InvariantsOfPendingRequests
&
InvariantsOfUserDirectory
```
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3.3.2 Authorization Process (Formal) TM-6862/181/88

InvariantsOfURPOwnedDevices =

A*U1,U2:URPOwnedDeviceEntry( U1<URPOwnedDevices & U2<URPOwnedDevices ->
   (U1.Raddr = U2.Raddr -> U1 = U2))
&
A*U:URPOwnedDeviceEntry( U<URPOwnedDevices ->
   Dominates(U,MaxSecLevel,U.MinSecLevel)
&
   DeviceType(Raddr) <: S"(Reader,Printer,Punch,TapeDrive)"
Invariants of NonsharableDrives =

A"NS1, NS2: NonsharableDriveEntry( NS1 <: NonsharableDrives & NS2 <: NonsharableDrives ->
  (NS1. Raddr = NS2. Raddr -> NS1 = NS2)) &

A"NS: NonsharableDriveEntry( NS <: NonsharableDrives ->
  Dominates NS.MaxSecLevel, NS.MinSecLevel) &

(NS. State = Attached ->
  E"N: NkcpsEntry( NS. CurrentNkcps &
    N. Process = NS. AttachedProcess &
    Dominates NS.MaxSecLevel, N. Process) &
    Dominates N. Process, NS. MinSecLevel) &
    E"A: AttachedDeviceEntry( A <: N. AttachedDevices &
      A. Raddr = NS. Raddr)))
3.3.2 Authorization Process (Formal) TH-6862/181/88

InvariantsOfSharableDrives =

A"S1, S2:SharableDriveEntry(S1<:SharableDrives & S2<:SharableDrives -->
(S1.Raddr = S2.Raddr --> S1 = S2))
&
A"S:SharableDriveEntry(S<:SharableDrives -->
(S.Stats = AttachedToSystem -->
E"V:SharedVolumeEntry(V<:SharedVolumes &
V.Volume = S.MountedVolume
&
V.State = Mounted
&
V.MountedDevice = S.Raddr
&
Dominates(S.SecLevel,V.SecLevel))))
InvariantsOfSharedVolumes = 

A"V1,V2:SharedVolumeEntry(V1<:SharedVolumes & V2<:SharedVolumes -> 
  (V1.Volume < V2.Volume -> V1 = V2))
&
A"V:SharedVolumeEntry(V<:SharedVolumes ->
  (V.State = Mounted ->
    E"S:ShareableDriveEntry(S<:ShareableDrives & 
      S.Raddr = V.MountedDevice 
      & 
      S.MountedVolume = V.Volume 
      & 
      S.State = AttachedToSystem 
      & 
      Dominates(S.SecLevel, V.SecLevel))))
3.3.2 Authorization Process (Formal)  

InvariantsOfMiniDisks =

A\["M1,M2:MiniDiskEntry(M1:\langle\text{MiniDisks}\& M2:\langle\text{MiniDisks}\rightarrow (M1.\text{MName} = M2.\text{MName} \rightarrow M1 = M2))\]

&
\[A\["M:MiniDiskEntry(M:\langle\text{MiniDisks} \rightarrow E\["V:SharedVolumeEntry(V:\langle\text{SharedVolumes} & V.\text{Volume} = M.\text{ContainingVolume} & Dominates(V.\text{SecLevel}, M.\text{SecLevel}))\]

&
M.\text{Cylinders.2} > M.\text{Cylinders.1} 
&
M.\text{Cylinders.1} < \#\text{Cylinders}(M.\text{ContainingVolume}) 
&
M.\text{Cylinders.2} <= \#\text{Cylinders}(M.\text{ContainingVolume}) 
&
A\["C:ProcessLinkEntry(C:\langle\text{CurrentLinks} \rightarrow C.\text{Access} = \text{Empty} 
&
E\["N:NkcpEntry(N:\langle\text{CurrentNkcps} & N.\text{Process} = C.\text{Process} 
&
E\["L:MDLinkEntry(L:\langle\text{Links} & L.\text{MName} = M.\text{MName} 
& L.\text{Access} = C.\text{Access}) 
&
E\["A:ACLEntry(A:\langle\text{AccessControlList} & E\["V:VMEntry(V:\langle\text{VMs} & V.\text{VName} = A.\text{User}) 
&
(Write (\langle C.\text{Access} \rightarrow N.\text{Process} = M.\text{SecLevel})) 
&
(M.\text{CurrentLinks} = \text{Empty} \rightarrow E\["V:SharedVolumeEntry(V:\langle\text{SharedVolumes} & V.\text{Volume} = M.\text{ContainingVolume} 
& V.\text{State} = \text{Mounted} 
& E\["S:ShareableDriveEntry(S:\langle\text{ShareableDrives} & S.\text{Raddr} = V.\text{MountedDevice} 
& S.\text{MountedVolume} = V.\text{Volume} 
& S.\text{State} = \text{AttachedToSystem})\]

&
A"A1.A2:ACLEntry(
   A1<i:M.AccessControlList & A2<i:M.AccessControlList ->
&
A"A:ACLEntry(A<i:M.AccessControlList ->
   E"D:DirectoryEntry(D<i:UserDirectory &
      D.UserId = A.User)
&
   A.Access = Empty))
InvariantsOfCurrentNkcps =

A"N1,N2:NkcpEntry(N1:<CurrentNkcps & N2:<CurrentNkcps ->
&a
A"N:NkcpEntry(N:<CurrentNkcps ->
    A"VM1,VM2:VMEntry(VM1:<N.VMs & VM2:<N.VMs ->
        (VM1.VMName = VM2.VMName -> VM1 = VM2))
    &
    A"AD1,AD2:AttachedDeviceEntry(AD1:<N.AttachedDevices & AD2:<N.AttachedDevices ->
        (AD1.Raddr = AD2.Raddr -> AD1 = AD2))
    &
    A"L1,L2:HDLinkEntry(L1:<N.Links & L2:<N.Links ->
        (L1.MName = L2.MName -> L1 = L2))
    &
    A"VM:VMEntry(VM:<N.VMs ->
        E"D:DirectoryEntry(D:<UserDirectory & D.UserId = VM.VMName
        &
        Dominates(D.MaxSecLevel,N.Process)
        &
        Dominates(N.Process,D.MinSecLevel))
        &
        (VM.Disconnected ->
            A"L:LineEntry(L:<Lines ->
                (L.AttachedVM = VM.VMName
                &
                L.RequestedSecLevel = N.Process
                &
                L.State = Attached) ->
                    L.Connection = Logon))
    &
    (!VM.Disconnected ->
        E"L:LineEntry(L:<Lines & L.Laddr = VM.Laddr
        &
        L.AttachedVM = VM.VMName
        &
        L.RequestedSecLevel = N.Process
        &
        L.Connection = Logon
        &
        L.State <= S"(AttachValidation,Attached))
    )
)
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3.3.2 Authorization Process (Formal)

A"U:LineAddress(U<:VM.Users ->
  E"L:LineEntry(L<:Lines &
    L.Laddr = U &
    L.AttachedVM = VM.VMName &
    L.RequestedSecLevel = N.Process &
    L.Connection = Dial &
    L.State <= S'(AttachValidation,Attached)
&
    U == VM.Laddr))
&
A"AD:AttachedDeviceEntry(AD<N.AttachedDevices ->
  E"NS:NonshareableDriveEntry(NS<NonshareableDrives &
    NS.Raddr = AD.Raddr &
    Dominates(NS.MaxSecLevel,N.Process) &
    Dominates(N.Process,NS.MinSecLevel))
&
  AD.Access == Empty)
&
A"L:MDLinkEntry(L<:N.Links ->
  E"M:MiniDiskEntry(M<MiniDisks &
    M.MDName = L.MDName &
    Dominates(N.Process,M.SecLevel))
&
  E"C:ProcessListEntry(C<:M.CurrentLinks &
    C.Process = N.Process &
    C.Access = L.Access)
&
  E"A:ACLEntry(A<:M.AccessControlList &
    E"VM:VMEntry(VM<:N.VMs &
      VM.VMName = A.User))
&
  (Write <: L.Access ->
    M.SecLevel = N.Process))
&
  L.Access == Empty))
&
A"N1,N2:NkcpeEntry(N1<:CurrentNkcps & N2<CurrentNkcps ->
  A"AD1,AD2:AttachedDeviceEntry(AD1<:N1.AttachedDevices & AD2<N2.AttachedDevices ->
    AD1.Raddr == AD2.Raddr))
InvariantsOfLines =
A"L1.L2:LineEntry(L1<:Lines & L2<:Lines ->
  L1.Laddr = L2.Laddr -> L1 = L2)"
&
A"L:LineEntry(L<:Lines ->
  Dominates(L.MaxSecLevel,L.MinSecLevel)
  &
  (L.State = AttachValidation ->
    L.CyclePosition <: S"(Retry,ReadInitialPassword,
    ReadAccessPassword,HookingPeripherals,
    NotifyingNkcp))"
&
(A"L:LineEntry(L<:Lines ->
  Dominates(L.MaxSecLevel,L.MinSecLevel)
  &
  (L.State = Attached ->
    L.CyclePosition <: S"(Attached,ReadLinkPassword))"
&
(A"L:LineEntry(L<:Lines ->
  Dominates(L.MaxSecLevel,L.MinSecLevel)
  &
  (L.State = Free ->
    L.CyclePosition <: S"(Disabled,Available,ReEnablePending))"
&
(A"L:LineEntry(L<:Lines ->
  Dominates(L.MaxSecLevel,L.MinSecLevel)
  &
  (L.State <: S"(AttachValidation,Attached) ->
    Dominates(L.MaxSecLevel,L.RequestedSecLevel)
    &
    Dominates(L.RequestedSecLevel,L.MinSecLevel))"
&
(A"L:LineEntry(L<:Lines ->
  E"N:NkcpEntry(N<:CurrentNkcp &
    N.Process = L.RequestedSecLevel
  &
  E"VM:VMEntry(VM<:N.VMs &
    VM.VMName = L.AttachedVM
  &
  (L.Connection = Logan ->
    VM.Laddr = L.Laddr
  &
    ~VM.Disconnected)
  &
  (L.Connection = Dial ->
    E"U:LineAddress(U<:VM.Users &
      U = L.Laddr)))))")
&
A^L1,L2:LineEntry(L1<Lines & L2<Lines ->
(L1.Raddr == L2.Raddr &
L1.State = Attached &
L2.State = Attached &
L1.AttachedVM = L2.AttachedVM &
L1.RequestedSecLevel = L2.RequestedSecLevel &
L1.Connection = Logon) ->
L2.Connection = Dial)
InvariantsOfPendingRequests =

A"P1,P2:PendingRequest(P1<:PendingRequests & P2<:PendingRequests ->
  (P1.MsgId = P2.MsgId -> P1 = P2))
&
A"P:PendingRequest(P<:PendingRequests ->
  A"R1,R2:ResponseSlot(R1<:P.Responses & R2<:P.Responses ->
    (R1.Respondent = R2.Respondent -> R1 = R2))
&
E"R:ResponseSlot(R<:P.Responses &
  R.State = NoResponse)
&
P.Responses == Empty)
3.3.2 Authorization Process (Formal)  

Invariants of User Directory:

A°D1,D2:DirectoryEntry(D1 < UserDirectory & D2 < UserDirectory ->
(D1.UserID = D2.UserID -> D1 = D2)) &
A°D:DirectoryEntry(D < UserDirectory ->
Dominates(D.MaxSecLevel,D.MinSecLevel)
&
A°D01,D02:DedicatedDeviceEntry(
D01 < D.DedicatedDevices & D02 < D.DedicatedDevices ->
(D01.Raddr = D02.Raddr -> D01 = D02)) &
A°D0:DedicatedDeviceEntry(D0 < D.DedicatedDevices ->
(DeviceType(D0.Raddr) <= S"(Reader,Printer,Punch,TapeDrive) ->
E°U:URPOwnedDeviceEntry(U < URPOwnedDevices &
D0.Raddr = U.Raddr
&
(DeviceType(D0.Raddr) = Reader ->
D0.VolSecLevel = nil
&
D0.Access = S"(Read))
&
(DeviceType(D0.Raddr) = S"(Printer,Punch) ->
D0.VolSecLevel = nil
&
D0.Access = S"(Write))
&
(DeviceType(D0.Raddr) = TapeDrive ->
Dominates(U.MaxSecLevel,D0.VolSecLevel)
&
Dominates(D0.VolSecLevel,U.MinSecLevel)
&
Dominates(D0.MaxSecLevel,D0.VolSecLevel)
&
D0.Access = Empty))
&
(DeviceType(D0.Raddr) = S"(Reader,Printer,Punch,TapeDrive) ->
E°NS:NonsharableDriveEntry(NS < NonsharableDrives &
NS.Raddr = D0.Raddr
&
Dominates(NS.MaxSecLevel,D0.VolSecLevel)
&
Dominates(D0.VolSecLevel,NS.MinSecLevel)
&
Dominates(D0.MaxSecLevel,D0.VolSecLevel)
&
D0.Access = Empty))) &
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A"L1, L2: MLinkEntry(L1:L:Links & L2:L:Links ->
(L1.MDName = L2.MDName -> L1 = L2))

A"L:MLinkEntry(L:<L:Links ->
E"M:MiniDiskEntry(M:<M:MiniDisks &
M.MDName = L.MDName
&
E"A:ACLEntry(A:<A:AccessControlList &
A.User = O.UserID
&
L.Access <= A.Access)
&
Dominates(D.MaxSecLevel, M.SecLevel))
&
L.Access -= Empty)
&
A"AP1. AP2: AccessPasswordEntry(
AP1:<AP1:AccessPasswords & AP2:<AP2:AccessPasswords ->
(AP1.SecLevel = AP2.SecLevel -> AP1 = AP2))
&
A"AP: AccessPasswordEntry(AP:<AP:AccessPasswords ->
Dominates(D.MaxSecLevel, AP.SecLevel)
&
Dominates(AP.SecLevel, O.MinSecLevel)))
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3.3.2 Authorization Process (Formal)  
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NTWK1: Network process message re line status (both request and response)

transform NTWK1(Laddr: LineAddress,  
CurrentLineStatus: LineCondition)

effect (¬(E"L:LineEntry(L<:Lines &  
L.Laddr = Laddr))  
=> Error ⇔ NoError &  
E"L:LineEntry(L<:Lines & L.Laddr = Laddr &  
N"Lines = Lines → S"(L) II  
S"(L.Laddr,  
L.MaxSecLevel,  
L.MinSecLevel,  
/L###/  
(L.State = Attached  
|  
(L.State = AttachValidation  
&  
L.CyclePosition<"S"(HookingPeripherals,  
NotifyingNkcp) ⇒  
Free  
<  L.State),  
/L###/  
(L.State = Attached  
|  
(L.State = AttachValidation  
&  
L.CyclePosition<"S"(HookingPeripherals,  
NotifyingNkcp) ⇒  
CurrentLineStatus  
<⇒ L.CyclePosition),  
L-RequestedSecLevel,  
/L###/  
(L.State = Attached  
|  
(L.State = AttachValidation  
&  
L.CyclePosition<"S"(HookingPeripherals,  
NotifyingNkcp) ⇒  
AuthProcess  
<⇒ L.AttachedVM),  
L.Connection,  
/L###/  
(L.State = AttachValidation  
&  
L.CyclePosition<"S"(HookingPeripherals,NotifyingNkcp) ⇒  
true  
<⇒ L.LineDropped),  
L.#Retries,  
L.#AwaitingHooks,  
L.Mag))  
&

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(L.State = Attached =>
E"N:NkcpEntry(/
N<:CurrentNkcp & N.Process = L.AttachedProcess &
E"V:VMEntry(V<:N.VMs & V.VMName = L.AttachedVM &
N"CurrentNkcp = CurrentNkcp => S"(N) II
S"(N.Process,
N.VMs => S"(V) II
S"(V.VMName,
V.Laddr,

/L#&/ (L.Connection = Logon
&
L.Laddr = V.Laddr =>
true

/L#&/
<> V.Disconnected),

(L.Connection = Dial
&
E"U:LineAddress(U<:V.Users &
U = L.Laddr) =>
V.Users => S"(L.Laddr)
<> V.Users)),
N.AttachedDevices,
N.Links)))

&
KernelCalled(SendMessage(OpProcess))
<> KernelCalled(SendMessage(Process))))

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LGDL1: Network Process message, LOGON or DIAL request received

transform LGDL1(Laddr: LineAddress, AttemptedCommand: AccessCategory, UserID: VirtualMachineName, RequestedSecLevel: ProcessName)

effect (\(\sim (E"\text{LineEntry}(\text{Lines} \land \text{Ladder} = \text{Ladder} \land \text{L.State} = \text{Free} \land \text{L.CyclePosition} = \text{Available})\))

=> Error <> NoError &
E"\text{LineEntry}(\text{Lines} \land \text{Ladder} = \text{Ladder} \land \text{N"Lines} = \text{Lines} \sim S"(L)) ||
(Dominaes(L.MaxSecLevel, RequestedSecLevel))
&
(Dominaes(RequestedSecLevel, L.MinSecLevel)) =>
S"((L.Ladder,
L.MaxSecLevel,
L.MinSecLevel,
/\#\#/ AttachValidation,
/\#\#/ ReadInitialPassword,
/\#\#/ RequestedSecLevel,
/\#\#/ UserID,
/\#\#/ AttemptedCommand,
/\#\#/ false,
/\#\#/ B,
/\#\#/ B,
/\#\#/ nil))

<= S"((L.Ladder,
L.MaxSecLevel,
L.MinSecLevel,
/\#\#/ Free,
/\#\#/ ReEnablePending,
L.RequestedSecLevel,
/\#\#/ AuthProcess,
L.Connection,
L.LineDropped,
L.#Retries,
L.#AwaitingHooks,
L.Msg))

&
N"PendingRequests = PendingRequests II
S"((NewFileId,

/###/
(Dominate(L.MaxSecLevel,RequestedSecLevel))
&
(Dominate(RequestedSecLevel,L.MinSecLevel) =>
  WriteAndReadLine
  -> ClearLine),

/###/
Undefined,
S"((NetworkProcess,
  nil,
  NoResponse)))
&
(Dominate(L.MaxSecLevel,RequestedSecLevel)
&
(Dominate(RequestedSecLevel,L.MinSecLevel) =>
  KernelCalled(SendMessage(NetworkProcess))
  -> KernelCalled(SendMessage(Network:Process))
  &
  KernelCalled(SendMessage(NetworkProcess))))

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LGDL2: Network Process message (Retry of LOGON or DIAL)

transform LGDL2(Laddr: LineAddress, 
    UserId: VirtualMachineName, 
    RequestedSecLevel: ProcessName)

refcond E"L:LineEntry(L<:Lines & 
    L.Laddr = Laddr 
    & 
    L.State = AttachValidation 
    & 
    L.CyclePosition = Retry)

effect E"L:LineEntry(L<:Lines & L.Laddr = Laddr & 
    N"Lines = Lines := S"(L) II 
    (Dominates(L:MaxSecLevel,RequestedSecLevel) 
    & 
    Dominates(RequestedSecLevel,L.MinSecLevel) => 
    S"((L.Laddr, 
        L.MaxSecLevel, 
        L.MinSecLevel, 
        L.State, 
        ReadInitialPassword, 
        RequestedSecLevel, 
        UserId, 
        L.Connection, 
        L.LineDropped, 
        L.#Retries, 
        L.#AwaitingHooks, 
        L.Msg))
    <> S"((L.Laddr, 
        L.MaxSecLevel, 
        L.MinSecLevel, 
        Free, 
        ReEnablePending, 
        LRequestedSecLevel, 
        AuthProcess, 
        L.Connection, 
        L.LineDropped, 
        L.#Retries, 
        L.#AwaitingHooks, 
        L.Msg))))
N"PendingRequests = PendingRequests II
S"((NewTagId,
  (Dominates(L.MaxSecLevel,RequestedSecLevel)
   &
   Dominates(RequestedSecLevel,L.MinSecLevel) =>
   WriteAndReadLine
   <-> ClearLine),
  Undefined,
  S"((NetworkProcess,
      nil,
      NoResponse))))
&
(Dominates(L.MaxSecLevel,RequestedSecLevel)
 &
 Dominates(RequestedSecLevel,L.MinSecLevel) =>
   KernelCalled(SendMessage(NetworkProcess))
 <-> KernelCalled(SendMessage(NetworkProcess))
 &
   KernelCalled(SendMessage(NetworkProcess))))
LGOL3: Userid, password, and requested security level validations

transform LGOL3(Laddr: LineAddress, Password: String)

refcond E"LiLineEntry(L<:Lines &
   L.Laddr = Laddr
   &
   L.State = AttachValidation
   &
   L.CyclePosition = ReadlnitialPassword)

effect E"LiLineEntry(L<:Lines & L.Laddr = Laddr &
   N"Lines = Lines ~ S"(L) II
   S"(L.Laddr,
   L.MaxSecLevel,
   L.MinSecLevel,
   /n#n/   (E"O:DirectoryEntry(O<:UserDirectory &
       O.UserID = L.AttachedVM
       &
       (L.Connection = Logon ->
        O.LogonPassword = Password)
       &
       (L.Connection = Dial ->
        O.DialPassword = Password)
       &
       ~ (Dominate(O.MaxSecLevel, L-RequestedSecLevel)
       &
       Dominate(L-RequestedSecLevel, O.MinSecLevel)))
   )
   L.#Retries + 1 = #MaxRetries =>
   Free
   <- L.State),

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(E"D:DirectoryEntry(0<;UserDirectory & D.UserID = L.AttachedVM & (L.Connection = Logon => D.LogonPassword = Password) & (L.Connection = Dial => D.DialPassword = Password)) => E"D:DirectoryEntry(0<;UserDirectory & D.UserID = L.AttachedVM & (Dominates(D.MaxSecLevel, L.RequestedSecLevel) & Dominates(L.RequestedSecLevel, D.MinSecLevel)) => E"A:AccessPasswordEntry( A<;D.AccessPasswords & A.SecLevel = L.RequestedSecLevel) => ReadAccessPassword => PerformResourceChecks) => ReEnablePending)) => (L.#Retries + 1 = #MaxRetries => ReEnablePending => Retry)), L.RequestedSecLevel).

/\##\/  \(E"D:DirectoryEntry(0<;UserDirectory & D.UserID = L.AttachedVM & (L.Connection = Logon => D.LogonPassword = Password) & (L.Connection = Dial => D.DialPassword = Password) & (Dominates(D.MaxSecLevel, L.RequestedSecLevel) & Dominates(L.RequestedSecLevel, D.MinSecLevel))))

L.#Retries + 1 = #MaxRetries => AuthProcess => L.AttachedVM), L.Connection, L.LineDropped,

/\##\/  \(E"D:DirectoryEntry(0<;UserDirectory & D.UserID = L.AttachedVM & (L.Connection = Logon => D.LogonPassword = Password) & (L.Connection = Dial => D.DialPassword = Password)) => L.#Retries + 1

L.#AwaitingHooks,
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E^Entry1, Entry2:PendingRequests(
    Entry1 = (NewMsgId,
              WriteAndReadLine,
              Undefined,
              S"((NetworkProcess,
                  nil,
                  NoResponse))
            )
    &
    Entry2 = (NewMsgId,
              ClearLine,
              Undefined,
              S"((NetworkProcess,
                  nil,
                  NoResponse))
            )
    &
    N^PendingRequests =
    (E^D:DirectoryEntry(D<UserDirectory &
                        D.UserId = L.AttachedVM
                        &
                        (L.Connection = Logon ->
                          D.LogonPassword = Password)
                        &
                        (L.Connection = Dial ->
                          D.DialPassword = Password)) =>
    E^D:DirectoryEntry(D<UserDirectory &
                        D.UserId = L.AttachedVM
                        &
                        (Dominates(D.MaxSecLevel, L.RequestedSecLevel)
                         &
                         Dominates(L.RequestedSecLevel, D.MinSecLevel)) =>
    (E^A:AccessPasswordEntry(
        A^D:AccessPasswords &
        A.SecLevel = L.RequestedSecLevel) =>
    PendingRequests || S"(Entry1)
    <> PendingRequests || S"(Entry2))
    <> (L.#Retries + 1 = #MaxRetries =>
    PendingRequests || S"(Entry2)
    <> PendingRequests || S"(Entry1)))
    &

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(E^0:DirectoryEntry(D:UserDirectory &
  D:UserId = L:AttachedVM &
  (L:Connection -: Logon ->
    O:LogonPassword = Password) &
  (L:Connection = Dial ->
    O:DialPassword = Password)) =>
  E^0:DirectoryEntry(D:UserDirectory & O:UserId = L:AttachedVM &
  (Dominates(D:MaxSecLevel,L:RequestedSecLevel) &
  Dominates(L:RequestedSecLevel,D:MinSecLevel) =>
  (E^A:AccessPasswordEntry(
    A:<0:AccessPasswords &
    A:SecLevel = L:RequestedSecLevel) =>
    KernelCalled(SendMessage(
      NetworkProcess))))
  => KernelCalled(SendMessage(
    NetworkProcess)))
  &
  KernelCalled(SendMessage(
    NetworkProcess)))
  => (N^L:#Retries = #MaxRetries =>
  KernelCalled(SendMessage(
    NetworkProcess)) &
  KernelCalled(SendMessage(
    NetworkProcess)))
  => KernelCalled(SendMessage(
    NetworkProcess))))
LGDL4: Perform access password checks

transform LGDL4(Laddr: LineAddress,
   AccessPassword: String)

refcond E"L:LineEntry(L<:Lines &
   L.Laddr = Laddr &
   L.State = AttachValidation &
   L.CyclePosition = ReadAccessPassword)

effect E"L:LineEntry(L<:Lines & L.Laddr = Laddr &
   ~E"D:DirectoryEntry(D<:UserDirectory &
     D.UserID = L.UserID &
       A.SecLevel = L-RequestedSecLevel))

=> Error <> NoError &
   E"D:DirectoryEntry(D<:UserDirectory &
     D.UserID = L.UserID &
       A.SecLevel = L.RequestedSecLevel &
       N"Lines = Lines ~ S"(L) II
       S"((L.Laddr,
           L.MaxSecLevel,
           L.MinSecLevel,
           /##x/
           (A.Password = AccessPassword &
            L.#Retries + 1 = #MaxRetries =>
            Free
            <> L.State),
           /##x/
           (A.Password = AccessPassword =>
            PerformResourceChecks
            <> (L.#Retries + 1 = #MaxRetries =>
             ReEnablePending
             <> Retry1),
            L.RequestedSecLevel,
           /##x/
           (A.Password = AccessPassword &
            L.#Retries + 1 = #MaxRetries =>
            AuthProcess
            <> L.AttachedVM),
            L.Connection,
            L.LineDropped,
           /##x/
           (A.Password = AccessPassword =>
            L.#Retries + 1
            <> L.#Retries),
            L.#AwaitingHooks,
            L.Msg)) &

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3.3.2 Authorization Process (Formal)

(A.AccessPassword => Password =>
N"PendingRequests = PendingRequests II
S"{(NewMsgId,
/L#Retries + 1 = #maxRetries =>
ClearLine
  => WriteAndReadLine),
/L#Retries + 1 = #maxRetries =>
Undefined,
S"{(NetworkProcess,
  nil,
  NoResponse)))
  => N"PendingRequests = PendingRequests)
&
(A.Password => AccessPassword =>
  Kernel Called(SendMessage(OpProcess)))
&
(L.#Retries + 1 = #maxRetries =>
  Kernel Called(SendMessage(
    NetworkProcess)))
&
  Kernel Called(SendMessage(
    NetworkProcess))
  => Kernel Called(SendMessage(
    NetworkProcess))))

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LGOLS: Perform resource checks

transform LGOLS(Laddr: LineAddress)
refcond E"L:LineEntry(L<:Lines & L.Laddr = Laddr)
effect E"L:LineEntry(L<:Lines & L.Laddr = Laddr &
  (~E"D:DirectoryEntry(D<:UserProfile & D.UserID = L.AttachedVM)
  & ~ShuttingDown))
  => Error <-> NoError &
  E"D:DirectoryEntry(D<:UserProfile & D.UserID = L.AttachedVM &
  /* not specified */ true))
LGDLG: Attach Dedicated Devices

transform LGDLG(Laddr: LineAddress)

refcond E"L:LineEntry(L<:Lines &
   L.Laddr = Laddr &
   L.State = AttachValidation &
   L.CyclePosition = HookingPeripherals)

effect E"L:LineEntry(L<:Lines & L.Laddr = Laddr &
   (~E"N:NkcpEntry(N<:CurrentNkcps &
      N.Process = L.AttachedProcess)
    &
    E"D:DirectoryEntry(D<:UserDirectory &
       D.UserId = L.AttachedVM))
   => Error <> NoError &
   E"D:DirectoryEntry(D<:UserDirectory & D.UserId = L.AttachedVM &
   /* not specified */ true)))
LGDL7: Perform Links at Logon

transform LGDL7(Laddr: LineAddress)
refcond E"L:LineEntry(L<:Lines & L.Laddr = Laddr & L.State = AttachValidation & L.CyclePosition = HookingPeripherals)

LGDL8: Response to message to NKCP re new VM

transform LGDL8(VM: VirtualMachineName,
   Process: ProcessName,
   Laddr: LineAddress)

refcond E"Li:LineEntry(L<:Lines &
   L.Laddr = Laddr)

effect E"Li:LineEntry(L<:Lines & L.Laddr = Laddr &
   ~(L.AttachedVM = VM
   &
   L.State = AttachValidation
   &
   L.CyclePosition = NotifyingNkcp)
   => Error => NoError &
   N"Lines = Lines => S"(L) 11
   S"(L.Laddr,
   L.MaxSecLevel,
   L.MinSecLevel,
   /s###/ (Responded(Process) =>
   Attached
   => (A"N:NkcpEntry(N<:CurrentNkcps ->
      N.Process == Process)
   &
   L.LineDropped =>
      Free
   => L.State)),

   /s###/ (Responded(Process) =>
   Attached
   => (E"N:NkcpEntry(N<:CurrentNkcps &
      N.Process == Process)
   | L.LineDropped =>
      L.CyclePosition
   => PerformResourceChecks)),
   L.RequestedSecLevel,
   L.AttachedVM,
   L.Connection,
   L.LineDropped,
   L.#Retries,
   L.#AwaitingHooks,
   L.Meg))

&
(Responded(Process) =>
  KernelCalled(SendMessage(NetworkProcess))
<> (E"N: NkcpEntry(N<:CurrentNkcp <
  N.Process = Process) =>
  KernelCalled(SendMessage(Process))
<> (L.Linedropped) =>
  KernelCalled(SendMessage(
  NetworkProcess))))))}
3.3.2 Authorization Process (Formal)

NKCP1: Disconnect

transform NKCP1(Process: ProcessName, VM: VirtualMachineName, Laddr: LineAddress, LineAction: String)
effect (~(E"N:NkcpEntry(N:<CurrentNkcp & N.Process = Process)
  &
  E"L:LineEntry(L:<Lines & L.Laddr = Laddr))
=> Error <= NoError &
E"L:LineEntry(L:<Lines & L.Laddr = Laddr &
  &
E"N:NkcpEntry(N:<CurrentNkcp & N.Process = Process &
N"Lines = Lines = S"(L)) &
S"(L.Laddr,
L.MaxSecLevel, L.MinSecLevel)

/###/
(E"V:VMEntry(V:<N.VMs &
V.VMName = VM &
V.Laddr = Laddr &
~V.Disconnected) => Free
<= L.State),

/###/
(E"V:VMEntry(V:<N.VMs &
V.VMName = VM &
V.Laddr = Laddr &
~V.Disconnected) => ReEnablePending
<= L.CyclePosition),
L.RequestedSecLevel,
L.AttachedVM,
L.Connection,
L.LineDropped,
L.#Retries,
L.#AwaitingHooks,
L.Msg))
3.3.2 Authorization Process (Formal)
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NKCP2: Logoff

transform NKCP2(Process: ProcessName,
VM: VirtualMachineName,
LineAction: String,
ReasonForLogoff: LogoffReasons)

effect (~(E"N:NkcpEntry(N<:CurrentNkcps &
N.Process = Process &
&
E"V:VMEntry(Y<:N.VMs &
V.VName = VM &
N"#Users =
(numberOfUsers - C"V.Users - 1
<= #User)
&
N"#VMs =
(numberOfVMs - 1
<= #VMs)
&
N"CurrentNkcps =
(numberOfNkcps)
&
N"PendingRequests =
(numberOfPendingRequests)
&
~ V.Disconnected =>
NumberOfRequests S"P;PendingRequest(1
E"U:LineAddress(U<:V.Users &
P=(NewFlagId,
ClearLine(U),
Undefined,
S"((NetworkProcess,
nil,
NoResponse))))))

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3.3.2 Authorization Process (Formal)

```plaintext
S"((NewMagid,
   (LineAction = 'hold' =>
    RedirectLine
   ) => ClearLine),
   Undefined,
   S"((NetworkProcess,
     nil,
     NoResponse)))
   => PendingRequests)

N"Lines = Lines

S"L:LineEntry(L<:Lines &
   E"U:LineAddress(U<:V.Users &
     U = L.Laddr))

S"L1:LineEntry(E"L:LineEntry(L<:Lines &
   E"U:LineAddress(U<:V.Users & U = L.Laddr &
    L1 = (L.Laddr,
     L.RequestedSeqLevel,
     Free,
     ReEnablePending,
     L.AttachedVM,
     L.Connection,
     L.LineDropped,
     L.ReTries,
     L.AwaitingHooks,
     L.Mag))))

KernelCalled(DestroyVM(V.VMName))

DestroyVM =>
  (V.Disconnected =>
    KernelCalled(SendMessage(OpProcess))
    => KernelCalled(SendMessage(OpProcess))
    &
    KernelCalled(SendMessage(
      NetworkProcess))
    &
    KernelCalled(SendMessage(
      NetworkProcess))
    &
    KernelCalled(SendMessage(
      AcntProcess))
    &
    A"U:LineAddress(U<:V.Users =>
      KernelCalled(SendMessage(
        NetworkProcess))
      &
      KernelCalled(SendMessage(
        NetworkProcess))))
    => KernelCalled(SendMessage(N.Process))))

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```
3.3.2 Authorization Process (Formal)

OP1: Autolog

transform OP1(UserId: VirtualMachineName, RequestedSecLevel: ProcessName, Password: String, AccessPassword: String)

effect ~(E"D:DirectoryEntry(D:<:UserDirectory &
  D.UserID = UserId &
  D.LogonPassword = Password &
  Dominates(D.MaxSecLevel,RequestedSecLevel)) &
  Dominates(RequestedSecLevel,D.MinSecLevel)) &
  D.Ipi0Defined = true &
    A.SecLevel = RequestedSecLevel ->
    A.Password = AccessPassword))

&
  ~ ShuttingDown &
  &
  Not VMs < #MaxVMs)
  => Error <-> NoError &
  /* not specified */ true)
3.3.2 Authorization Process (Formal)

UR2 and OP2: Map user id

transform UR2(UserId: VirtualMachineName, Requester: ProcessName)
refcond Requester <: \(S\)"(OpProcess, URProcess)
effect KernelCalled(SendMessage(Requester))
OP4b: Detach of shared device (by operator)

transform OP4b(Raddr: DeviceAddress)

refcond E"S:ShareableDriveEntry(S<ShareableDrives & S.Raddr = Raddr)

effect E"S:ShareableDriveEntry(S<ShareableDrives & S.Raddr = Raddr &
  N"ShareableDrives = ShareableDrives ~ S"(S) &
  S"(S.Raddr,
  /*##*/  S.State = AttachedToSystem &
  A"M:MiniDiskEntry(M<MiniDisks &
    M.ContainingVolume = S.MountedVolume ->
    M.CurrentLinks = Empty)
  &
  DevicesReleasable &
  DeviceReleased =>
    Available
    => S.State),
  S.SecLevel,
  S.MountedVolume))
&
(S.State = AttachedToSystem &
 A"M:MiniDiskEntry(M<MiniDisks &
    M.ContainingVolume = S.MountedVolume ->
    M.CurrentLinks = Empty)
 &
 DevicesReleasable &
 DeviceReleased =>
 E"V:SharedVolumeEntry(V<SharedVolumes &
 V.MountedDevice = S.MountedVolume &
 N"SharedVolumes = SharedVolumes ~ S"(V) &
 S"((V.Volume,
  V.SecLevel,
 nil,
 NotMounted))))
& KernelCalled(SendMessage(OpProcess))
& (S.State = AttachedToSystem ->
  (A"M:MiniDiskEntry(M:<MiniDisks &
    M.ContainingVolume = S.MountedVolume ->
    M.CurrentLinks = Empty) ->
    KernelCalled(IsDeviceReleasable)
    &
    (DeviceIsReleasable ->
    KernelCalled(ReleaseDevice))))

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OP4a: Detach of nonshared device (by operator)

transform OP4a(Raddr: DeviceAddress)

refcond E"NS:NonsharableDriveEntry(NS<:NonsharableDrives & NS.Raddr = Raddr)

effect E"NS:NonsharableDriveEntry(
    NS<:NonsharableDrives & NS.Raddr = Raddr &
    N"NonsharableDrives = NonsharableDrives & S"(NS) II
    S"{(NS.Raddr,
        NS.MaxSecLevel,
        NS.MinSecLevel,
    )/
    (NS.State = AttachedToUser =>
        DetachPending
        <> NS.State),
        NS.AttachedProcess,
        NS.Access))
&
N"PendingRequests =
    (NS.State = AttachedToUser =>
        PendingRequests II
        S"{(NewMsgId,
            RelinquishDevice,
            DETACH+ADDR,
            S"{(NetworkProcess,
                nil,
                NoResponse)\)}}
        <> PendingRequests)
&
(NS.State = AttachedToUser =>
    KernelCall(SendMessage(NS.AttachedProcess))
    <> (NS.State <> S"(OffLine, Available) =>
        KernelCalled(SendMessage(OpProcess))))
OP5a: Vary (both online and offline) of shared device

transform OP5a(Raddr: DeviceAddress,
   Parameter: String)

refcond E"ShareableDriveEntry(S<:ShareableDrives &
   S.Raddr = Raddr)

effect (Parameter \ll S"('online, 'offline')
   \ll Error \ll NoError &
   E"ShareableDriveEntry(
      S<:ShareableDrives & S.Raddr = Raddr &
      N"ShareableDrives = ShareableDrives \ll S"(S)) &
   S"(S.Raddr,
      \ll Parameter = 'online' =>
      Available
      \ll Offline),
      S.SecLevel,
      S.MountedVolume)
   &
   KernelCalled(SendMessage(OpProcess))))
3.3.2  Authorization Process (Formal)   

OPSb: Vary (both online and offline) of nonshared device

transform OPSb(Raddr: DeviceAddress, 
        Parameter: String)
refcond E"NS:NonsharableDriveEntry(NS<=NonsharableDrives & 
        NS.Raddr = Raddr)
effect (Parameter ::= S"('online', 'offline')
        => Error <- NoError & 
        E"NS:NonsharableDriveEntry(
        NS<=NonsharableDrives & NS.Raddr = Raddr & 
        N"NonsharableDrives = NonsharableDrives ~ S"(NS) ||
        S"(NS.Raddr, 
        NS.MaxSecLevel, 
        NS.MinSecLevel, 
        /###/ (Parameter = 'online' => 
        Available 
        <- Offline), 
        NS.AttachedProcess, 
        NS.Access))
        & 
        KernelCalled(SendMessage(OpProcess))))
OPGa: QUERY, with parameters:
   DASD
   LINES
   GRAF
   ALL
   NAMES
   USERS with no further parameter

transform OPGa(Command:CommandName)
refcond Command<=CatGa
effect KernelCalled(SendMessage(OpProcess))
OP6b: QUERY, with parameters:

\[ \text{raddr} \text{ SYSTEM raddr} \]

transform OP6b(Command: CommandName, Raddr: DeviceAddress)

refcond Command<:Cat6b

effect \((\neg (E"S:\text{ShareableDriveEntry}(S<:\text{ShareableDrives} \& \\ \quad S.\text{Raddr} = \text{Raddr}) \\
\quad \lor \\
E"NS:\text{NonshareableDriveEntry}(NS<:\text{NonshareableDrives} \& \\
\quad NS.\text{Raddr} = \text{Raddr}) \\
\Rightarrow \text{Error} \leftrightarrow \text{NoError} \& \\
\text{KernelCalled}(\text{SendMessage}(\text{OpProcess})))\)
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3.3.2 Authorization Process (Formal) TII-9662/181/80

OP6c: QUERY, with parameters:
   USERS userid

transform OP6c(Command: CommandName,
   UserId: VirtualMachineName)

recond Command<:Cat6c

effect KernelCalled(SendMessage(OpProcess))
OP7: LOCATE+RADDR

transform OP7(Raddr: DeviceAddress)

refcond E"NS:NonsharableDriveEntry(NS<:NonsharableDrives & NS.Raddr = Raddr)

effect E"NS:NonsharableDriveEntry(
   NS<:NonsharableDrives & NS.Raddr = Raddr &
   N°PendingRequests =
   (NS.State = AttachedToUser => PendingRequests !)
   S"((NewMsgId, OpCode, LOCATE+RADDR,
      PendingRequests))

&
   (NS.State = AttachedToUser =>
      KernelCalled(SendMessage(NS.AttachedProcess))
      => KernelCalled(SendMessage(OpProcess}))"
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3.3.2 Authorization Process (Formal)

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OP8: Shutdown

transform OP8

effect N"ShuttingDown = true
OP3: Attach (nonshareable disk drive) Device

transform OP3(Raddr: DeviceAddress,
         Process: ProcessName,
         VolSecLevel: ProcessName,
         Access: set of AccessModes)

refcond E^NS:NonshareableDriveEntry(NS<:NonshareableDrives &
         * NS.Raddr = Raddr)

effect E^NS:NonshareableDriveEntry(
         NS<:NonshareableDrives & NS.Raddr = Raddr &
         (~E^NS:NkcpEntry(N<:CurrentNkcps &
         N.Process = Process &
         & A"A:AttachedDeviceEntry(A<:N.AttachedDevices ->
         A.Raddr = Raddr)
         & NS.State = Free &
         Dominates(N.Process,VolSecLevel) &
         Dominates(NS.MaxSecLevel,N.Process) &
         Dominates(N.Process,NS.MinSecLevel) &
         Dominates(NS.MaxSecLevel,VolSecLevel) &
         Dominates(VolSecLevel,NS.MinSecLevel))
         & Access = Empty &
         & ~ShuttingDown)
=> Error <> NoError &
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3.3.2 Authorization Process (Formal)  TH-6852/101/08

```
E^N:NilkcpEntry(N<:CurrentNkcpp & N.Process = Process &
N"NonshareableDrives = NonshareableDrives = S"(NS) ||
S"((NS.Raddr,
NS.MaxSecLevel,
NS.MinSecLevel,

/###/   (Write<:Access & VolSecLevel <- N.Process ->
/###/     Access <- S"(Write) <- Access) <- Empty
     &
     GrantedAccess =>
     Attached,
     => NS.State),
/###/   (Write<:Access & VolSecLevel <- N.Process ->
/###/     Access <- S"(Write) <- Access) <- Empty
     &
     GrantedAccess =>
     N.Process
     => NS.AttachedProcess),
/###/   (Write<:Access
     &
     VolSecLevel <- N.Process ->
     Access <- S"(Write)
     <- Access)))

&
N"CurrentNkcpp = CurrentNkcpp = S"(N) ||
S"((N.Process,
N.VMs,

/###/   (Write<:Access & VolSecLevel <- N.Process ->
/###/     Access <- S"(Write) <- Access) <- Empty
     &
     GrantedAccess =>
     NS.AttachedDevices ||
     S"((NS.Raddr,
     NS.Access)
     => N.AttachedDevices),
N.Links))

&
((Write<:Access & VolSecLevel <- N.Process ->
Access <- S"(Write)
<- Access)
= Empty =>
KernelCalled(SendMessage(OpProcess))
<= KernelCalled(GrantAccess)
&
(GrantedAccess =>
KernelCalled(SendMessage(N.Process))
&
KernelCalled(SendMessage(OpProcess))
<= KernelCalled(SendMessage(OpProcess))))
```
transform URI (RequestedSecLevel, ProcessName, Raddr, DeviceAddress)

effect (A"D:URPOwnedDeviceEntry (D<:URPOwnedDevices -> D.Raddr == Raddr)
   => Error => NoError & E"D:URPOwnedDeviceEntry (D<:URPOwnedDevices & D.Raddr = Raddr &
   N"#Nkcps =
   (A"N: NkcpsEntry (N<:CurrentNkcps ->)
    N.Process == RequestedSecLevel)
   &
    Dominates (D.MaxSecLevel, RequestedSecLevel)
   &
    Dominates (RequestedSecLevel, D.MinSecLevel)
   &
    #Nkcps < #MaxNkcps
   &
    CreatedProcess =>
    #Nkcps + 1
   <= #Nkcps)

&

N"CurrentNkcps =
   (A"N: NkcpsEntry (N<:CurrentNkcps ->)
    N.Process == RequestedSecLevel)
   &
    Dominates (D.MaxSecLevel, RequestedSecLevel)
   &
    Dominates (RequestedSecLevel, D.MinSecLevel)
   &
    #Nkcps < #MaxNkcps
   &
    CreatedProcess =>
    CurrentNkcps ++
    $"((RequestedSecLevel, Empty, Empty, Empty))
   <= CurrentNkcps)

&
3.3.2 Authorization Process (Formal)
3.3.2 Authorization Process (Formal)

UR3a: UProcess response to device attachment request (attach succeeded)

transform UR3a(Raddr: DeviceAddress, 
Process: ProcessName, 
Laddr: LineAddress)

effect (~E"A:URPOwnerDeviceEntry(A<:URPOwnerDevices & 
A.Raddr = Raddr) 
& 
E"N:NkcpEntry(N<:CurrentNkcps & 
N.Process = Process) 
& 
E"L:LineEntry(L<:Lines & 
L.Laddr = Laddr 
& 
L.State = AttachValidation 
& 
L.CyclePosition = HookingPeripherals 
& 
L.#AwaitingHooks > 0)) 
=> Error <> NoError & 
E"L:LineEntry(L<:Lines & L.Laddr = Laddr & 
N"Lines = Lines ~> S"(L) II 
S"(L.Laddr, 
L.MinSecLevel, 
L.MaxSecLevel, 
L.State, 
L.#AwaitingHooks - 1 = 0 ~> 
NotifyingNkcp, 
<> L.CyclePosition), 
L.RequestedSecLevel, 
L.AttachedVM, 
L.Connection, 
L.LineDropped, 
L.#Retries, 
L.#AwaitingHooks - 1, 
Concat(L.MsgAvail(Raddr))))
Authorization Process (Formal)

N"PendingRequests =
   (L.#AwaitingHooks - 1 = 0 =>
      PendingRequests ||
      S"((NewMagId,
         NewVM,
         Undefined,
         S"((Process,
            nil,
            NoResponse)))))
   <> PendingRequests)
S(L.#AwaitingHooks - 1 = 0 ->
   (~L.LineDropped ->
      KernelCalled(SendMessage(
         NetworkProcess)))))
S(KernelCalled(SendMessage(Process))))
UR3b: URProcess response to device attachment request (attach failed)

transform UR3b(Raddr: DeviceAddress,
               Process: ProcessName,
               Laddr: LineAddress)

effect (~(E"A:URPOwnerDeviceEntry(A<URPOwnerDevices &
                        A.Raddr = Raddr)
                   
                   &
                   E"N:NkcpEntry(N<CurrentNkcps &
                        N.Process = Process)
                   
                   &
                   E"L:LineEntry(L<Lines &
                        L.Laddr = Laddr
                        &
                        L.State = AttachValidation
                        &
                        L.CyclePosition = HookingPeripherals
                        &
                        L.#AwaitingHooks > 0))

   => Error <= NoError &
   E"L:LineEntry(L<Lines & L.Laddr = Laddr &
                  N"Lines = Lines ~ S"(L)
                  S"(L.Laddr,
                  L.MaxSecLevel,
                  L.MinSecLevel,
                  L.State,
                  /##SIDE
                  L.#AwaitingHooks - 1 = 0 =>
                      NotifyingNkcp
                      <= L.CyclePosition),
                  L.RequestedSecLevel,
                  L.AttachedVM,
                  L.Connection,
                  L.LineDropped,
                  L.#Retries,
                  /##SIDE
                  L.#AwaitingHooks - 1,
                  /##SIDE
                  Concat(L.Mag, Unavail(Raddr))))

&
N"PendingRequests =
(L.#AwaitingHooks - 1 = 0 =>
   PendingRequests II
   S"((NewMsgId,
      NewVM,
      Undefined,
      S"((Process,
          nil,
          NoResponse)),
         <> PendingRequests))
   <> PendingRequests)
&
(L.#AwaitingHooks = 1 - 0 ->
   (~L.LineDropped ->
     KernelCalled(SendMessage(
          NetworkProcess)))
   &
     KernelCalled(SendMessage(Process))))
NKCP3: Drop User

transform NKCP3 (Process: ProcessName, VM: VirtualMachineName, Laddr: LineAddress)

effect (~E"N:LineEntry(N<:CurrentNkcps & 
  N.Process = Process 
  
  E"V:VMEntry(V<:N.VMs & 
    V.VMName = VM 
    & 
    E"U:LineAddress(U<:V.Users & 
      U = Laddr)))

  & 
  E"L:LineEntry(L<:Lines & 
    L.Laddr = Laddr 
    & 
    L.State = Attached 
    & 
    L.Connection = Dial 
    & 
    L.AttachedVM = VM))

  => Error <> NoError & 
  E"L:LineEntry(L<:Lines & L.Laddr = Laddr & 
    N"Lines = Lines ~ S"(L) II 
    S"((L.Laddr, 
      L.MinSecLevel, 
      L.MaxSecLevel, 
      L.Mag)) 
    /&/ReEnablePending, 
    /&/ReEnablePending, 
    LRequestedSecLevel, 
    L.AttachedVM, 
    L.Connection, 
    L.LineDropped, 
    L.Retry, 
    L.WaitingHooks, 
    L.Mag)) 

&
3.3.2 Authorization Process (Formal)

E"N:Entry(N<:CurrentNkcp & N.Process = Process &
E"V:Entry(V<:N.VMs & V.VName = VM &
N"CurrentNkcp = CurrentNkcp & S"(N) ~
S"(N.Process,
N.VMs " S"(V) ~
S"(V.VName,
V.Laddr,
V.Disconnected,
V.Users " S"(Laddr)),
N.AttachedDevices,
N.Links))),

& N"PendingRequests = PendingRequests II
S"(NewMsgId,
ClearLine,
Undefined,
S"(NetworkProcess,
nil,
NoResponse)))

& KernelCalled(SendMessage(NetworkProcess))
& KernelCalled(SendMessage(OpProcess))
& KernelCalled(SendMessage(AcntProcess))

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NTWK3: Link password received


refcond E"L:LineEntry(L<:Lines & L.Laddr = Laddr & L.State = Attached & L.CyclePosition = ReadLinkPassword)

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(RequestedAccess = R =>
  (A\"C:ProcessLinkEntry(C:\:\M:CurrentLinks =>
    Write <<< C:Access) =>
    Link (N, Process, M:MDName, S" (Read))
    => NoLink (PreviousWriteLink))

  RequestedAccess = RR =>
    Link (N, Process, M:MDName, S" (Read))

  RequestedAccess = W =>
    (Write <<< A:Access =>
      (M:CurrentLinks = Empty =>
        Link (N, Process, M:MDName, S" (Write))
        => NoLink (PreviousLink))
      => NoLink (NoWritePermission))

  RequestedAccess = WR =>
    (Write <<< A:Access =>
      (M:CurrentLinks = Empty =>
        Link (N, Process, M:MDName, S" (Write))
        => NoLink (NoWritePermission))

  RequestedAccess = M =>
    (Write <<< A:Access =>
      (A\"C:ProcessLinkEntry(C:\:\M:CurrentLinks =>
        Write <<< C:Access) =>
        Link (N, Process, M:MDName, S" (Write))
        => NoLink (PreviousWriteLink))

  RequestedAccess = MR =>
    (Write <<< A:Access =>
      (A\"C:ProcessLinkEntry(C:\:\M:CurrentLinks =>
        Write <<< C:Access) =>
        Link (N, Process, M:MDName, S" (Write))
        => Link (N, Process, M:MDName, S" (Read))

        /\ choices: Link (N, Process, M:MDName, S" (Read))
        NoLink (NoWritePermission) \/
        NoLink (NoWritePermission)

  RequestedAccess = MW =>
    (Write <<< A:Access =>
      Link (N, Process, M:MDName, S" (Write))
      => NoLink (NoWritePermission))

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transform Link (Process: ProcessName, MiniDisk: MiniDiskName, Access: set of AccessModes)
effect E"N:NkcpEntry(N:\CurrentNkcp & N.Process = Process &
E"M:MiniDiskEntry(Mc:MiniDisks & M.MDName = MiniDisk &
(E"M:ProcessLinkEntry(
MPL<\M.CurrentLinks & MPL.Process = N.Process) =>
E"M:ProcessLinkEntry(
MPL<\M.CurrentLinks & MPL.Process = N.Process &
E"M:MDLinkEntry(NML<\N.Links & NML.MDName = M.MDName &
(Access <<< MPL.Access ->
KernelCalled(GrantAccess)
&
(GrantedAccess =>
N"CurrentNkcp = CurrentNkcp => S"(N)
S"((N.Process,
N.VMs,
N.AttachedDevices,
N.Links => S"(NML)
S"((NML.MDName,
Access))))
&
N"MiniDisks = MiniDisks => S"(M)
S"((M.MDName,
M.ContainingVolume,
M.Cylinders,
M.SecLevel,
M.CurrentLinks => S"(MPL)
S"((MPL.Process,
Access)),
M.AccessControlList))
=> N"CurrentNkcp = CurrentNkcp
&
N"MiniDisks = MiniDisks))")
=> KernelCalled(GrantAccess)
&
(GrantedAccess =>
"CurrentNkcps = CurrentNkcps \text~ S" (N) II
S" (N.Process,
  N.VMs,
  N.AttachedDevices,
  N.Links II
S" ((M.MOName,
       Access))))
&
N"MiniDisks = MiniDisks \text~ S" (M) II
S" ((M.MOName,
       M.ContainingVolume,
       M.Cylinders,
       M.SecLevel,
       M.CurrentLinks II
S" ((N.Process,
       Access)),
       M.AccessControlList))
<br>
\begin{verbatim}
< N"CurrentNkcps = CurrentNkcps
&
N"MiniDisks = MiniDisks)))))
\end{verbatim}
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3.3.2 Authorization Process (Formal)

NKCP4: Link (with password)

transform NKCP4(Process: ProcessName, 
  Requester: VirtualMachineName, 
  Laddr: LineAddress, 
  User: VirtualMachineName, 
  MiniDisk: MiniDiskName, 
  RequestedAccess: LinkAccess)

effect (ShuttingDown
  RequestedAccess = Empty
  => Error => NoError & 
  (E"N:NkcpEntry(N<CurrentNkcp) & 
   N.Process = Process
   & 
   E"E:"Entry(E<:N.VMs & 
   E.VName = Requester)
   & 
   E"L:LineEntry(L<:Lines & 
   L.Laddr = Laddr
   & 
   L.State = Attached
   & 
   L.CyclePosition = Attached
   & 
   LRequestedSecLevel = Process
   & 
   L.AttachedVM = Requester)
   & 
   E"D:DirectoryEntry(D<:UserDirectory & 
   D.UserID = User
   & 
   E"K:MDLinkEntry(K<:K Links & 
   K.MName = MiniDisk)
   & 
   E"M:MiniDiskEntry(M<:MiniDisks & 
   M.MName = MiniDisk
   & 
   E"A:ACLEntry(A<:M.AccessControlList & 
   A.User = Requester
   & 
   Dominates(Process, M.SecLevel)
   & 
   (Write<:RequestedAccess -> 
   Process = M.SecLevel))

  &

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E"V:SharedVolumeEntry(V<:SharedVolumes &
V.Volume = M.ContainingVolume &
V.State = Mounted &
E"S:SharableDriveEntry(S<:SharableDrives &
S.Raddr = V.MountedDevice &
S.State = AttachedToSystem)) =>
KernelCalled(SendMessage(NetworkProcess))
& KernelCalled(SendMessage(NetworkProcess))
&
E"L:LineEntry(L<:Lines & L.Laddr = Laddr &
N"Lines = Lines => S"(L) II
S"((L.Laddr,
L.MaxSecLevel,
L.MinSecLevel,
L.State,
L.CyclePosition,
L.RequestedSecLevel,
L.AttachedVM,
L.Connection,
L.LineDropped,
L.#Retries,
L.#WaitingHooks,
L.Msg)))
&
N"PendingRequests = PendingRequests II
S"((NewMsgId,
WriteAndReadLine,
Undefined,
S"((NetworkProcess,
nil,
NoResponse))))
<> N"Lines = Lines
&
N"PendingRequests = PendingRequests
&
KernelCalled(SendMessage(Process)))
NKCP5, NKCPG: Detach nonshareable device (request from process),
and response (from process) to relinquish device request from
Authprocess

transform NKCP5(Raddr: DeviceAddress,
    Process: ProcessName,
    User: VirtualMachineName)
    (~(E"N:NkcpEntry(N:\CurrentNkcps &
        N.Process = Process
        &
        E"VM:VMEntry(VM:\N.VMs &
            VM.VMName = User)
        &
        E"A:AttachedDeviceEntry(A\N.AttachedDevices &
            A.Raddr = Raddr))
        &
        E"NS:NonshareableDriveEntry(NS:\NonshareableDrives &
            NS.Raddr = Raddr
            &
            NS.AttachedProcess = Process)
    )
    => Error <> NoError &
    E"NS:NonshareableDriveEntry, N:NkcpEntry(
        NS:\NonshareableDrives & NS.Raddr = Raddr &
        N:\CurrentNkcps & N.Process = Process &
        N"NonshareableDrives = NonshareableDrives &&
        S"(NS) II
        S"((NS.Raddr,
            NS.MaxSecLevel,
            NS.MinSecLevel,
            (DeviceReleased =>
                Available
                <> NS.State),
            NS.AttachedProcess,
            NS.Access))
    )
    &
    N"CurrentNkcps = CurrentNkcps &&
    S"((N.Process,
        N.VMs,
        (DeviceReleased =>
            N.AttachedDevices --
            S"A:AttachedDeviceEntry(
                A\N.AttachedDevices
                &
                A.Raddr = NS.Raddr)
            <> N.AttachedDevices),
            N.Links))

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3.3.2 Authorization Process (Formal)

&
Kernel Called (ReleaseDevice (NS.Raddr))
&
Kernel Called (SendMessage (OpProcess))
&
(Device Released =>
  Kernel Called (SendMessage (AcntProcess'))
  <> Kernel Called (SendMessage (NS.AttachedProcess'))
)
NKCP7: Purge NKCP

transform NKCP7 (Process: ProcessName)

effect (~E"N:NkcpEntry (N<:CurrentNkcp &
  N.Process = Process
  &
  N.VMs = Empty
  &
  N.AttachedDevices = Empty
  &
  N.Links = Empty))
  => Error <> NoError &
  E"N:NkcpEntry (N<:CurrentNkcp & N.Process = Process &
  N"CurrentNkcp = CurrentNkcp ~ S"(N)))
KERNI: message from Kernel, re shared device availability

transform KERNI
(Raddr, DeviceAddress,
 VolumeId, VolumeId,
 CurrentStatus, SharedDriveStatus)

effect (~(E"S:SharableDriveEntry(S<:SharableDrives &
   S.Raddr = Raddr
   &
   (CurrentStatus = AttachedToSystem ->
    E"V:SharedVolumeEntry(V<:SharedVolumes &
     V.Volume = Volume))))
   -> Error <> NoError &
   E"S:SharableDriveEntry(S<:SharableDrives & S.Raddr = Raddr &
   (S.State = AttachedToSystem ->
    (CurrentStatus = AttachedToSystem ->
     (Volume = S.MountedVolume ->
      (E"M:MiniDiskEntry(M<:MiniDisks &
       M.ContainingVolume = S.MountedVolume
       &
       M.CurrentLinks <> Empty) =>
      Error
     )
   )
   > E"Vold, Vnew:SharedVolumeEntry(
   Vold<:SharedVolumes & Vnew<:SharedVolumes &
   Vold.Volume = S.MountedVolume
   &
   Vold.State = Mounted
   &
   Vold.MountedDevice = S.Raddr
   &
   Vnew.Volume = Volume
   &
   (Dominates(S.SecLevel, Vnew.SecLevel) =>
    N"SharableDrives = SharableDrives ~ S"(S) II
    S"((S.Raddr,
    S.State,
    S.SecLevel,
    Vnew.Volume))
   &
   N"SharedVolumes = SharedVolumes
   ~ S"(Vold, Vnew)
   II
   S"((Vold.Volume,
    Vold.SecLevel,
    nil, NotMounted))
   II
   S"((Vnew.Volume,
    Vnew.SecLevel,
    S.Raddr,
    Mounted))
   &

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KernelCalled(DriveMatchesVolume)
<> N"SharableDrives = SharableDrives
&
N"SharedVolumes = SharedVolumes
&
KernelCalled(DriveDoesNotMatchVolume)))
<> N"SharableDrives = SharableDrives
&
N"SharedVolumes = SharedVolumes
&
KernelCalled(DriveMatchesVolume))
<> E"V:SharedVolumeEntry(V<:SharedVolumes
V.Volume = S.MountedVolume
&
V.State = Mounted
&
V.MountedDevice = S.Raddr
N"SharableDrives = SharableDrives ~ S"(S) II
S"((S.Raddr,
CurrentStatus,
S. SecLevel,
nil))
&
N"SharedVolumes = SharedVolumes ~ S"(V) II
S"((V.Volume,
V. SecLevel,
nil,
NotMounted)))
<> (CurrentStatus = AttachedToSystem =>
E"V:SharedVolumeEntry(V<:SharedVolumes
V.Volume = Volume
&
(Dominate(S.SecLevel, V.SecLevel) =>
N"SharableDrives = SharableDrives ~ S"(S) II
S"((S.Raddr,
AttachedToSystem,
S. SecLevel,
V.Volume))
&
N"SharedVolumes = SharedVolumes ~ S"(V) II
S"((V.Volume,
V. SecLevel,
S.Raddr,
Mounted))
&
KernelCalled(DriveMatchesVolume)
<> N"SharableDrives = SharableDrives
&
N"SharedVolumes = SharedVolumes
&
KernelCalled(DriveDoesNotMatchVolume)))
<> N"SharableDrives = SharableDrives \land S"(S) \land S"((S.Raddr, CurrentStatus, S.SecLevel, S.Volume)))}
transform MsgOp(MsgId: MessageId,
    Text: String,
    Source: ProcessName)

refcond Source = OpProcess

effect (E"P:PendingRequest(P<:PendingRequests
    & P.MsgId = MsgId) =>

    Error
    => (MsgName(Text) = AUTOLOG =>
        OP1
        => MsgName(Text) = ATTACH-RADDR =>
            (E"NS: NonsharableDriveEntry(NS<:NonsharableDrives &
                    NS.Raddr = Raddr(Text))) =>
                OP3
                => Error)
        => MsgName(Text) = DETACH-RADDR =>
            (E"NS: NonsharableDriveEntry(NS<:NonsharableDrives &
                    NS.Raddr = Raddr(Text))) =>
                OP4a
                => E"S: SharableDriveEntry(S<:SharableDrives &
                        S.Raddr = Raddr(Text)) =>
                    OP4b
                => Error)
        => MsgName(Text)<:Cat6a =>
            OP6a
        => MsgName(Text)<:Cat6b
            OP6b
        => MsgName(Text)<:Cat6c =>
            OP6c
        => MsgName(Text) = LOCATE-RADDR =>
            OP7a
        => MsgName(Text) = SHUTDOWN =>
            OP8
        => MsgName(Text) = MapUserId =>
            OP2
        => Error))
transform MsgUR(MsgId: MessageId, Text: String, Source: ProcessName)

refcond Source = UNProcess

effect (E"P: PendingRequest(P<:PendingRequests & P.MsgId = MsgId) => E"P: PendingRequest(P<:PendingRequests & P.MsgId = MsgId & (P.Kind = Attach => MsgName(Text) = Attached => UR3n
   => MsgName(Text)<:S"(AttachFailed,DeviceNotAvailable) => UR3n
   => Error)
   => Error))
   => (MsgName(Text) = NeedNkcp => UR1)
   => MsgName(Text) = MapUserID => UR2
   => Error))

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3.3.2 Authorization Process (Formal)

transform MsgNet(MsgId; MessageId, Text: String, Source: ProcessName)

refcond Source = NetworkProcess
effect (E"P:PendingRequest(P<:PendingRequests & P.MsgId = MsgId) =>
E"P:PendingRequest(P<:PendingRequests & P.MsgId = MsgId &
  (P.Kind = S"(ClearLine, ReDirectLine) =>
    (MsgName(Text) = LineStatus =>
      NtWk1
    <> Error)
  <> P.Kind = WriteAndReadLine =>
    (MsgName(Text) = LineInfo =>
      E"L:LineEntry(L<:Lines &
        L.Laddr = Laddr(Text)) =>
      E"L:LineEntry(L<:Lines &
        L.Laddr = Laddr(Text) &
        L.State = Attached =>
          (L.CyclePosition = ReadLinkPassword =>
            NtWk3
          <> Error)
  <> L.State = AttachValidation =>
    (L.CyclePosition = Retry =>
      LGDL2
  <> L.CyclePosition = ReadInitialPassword =>
      LGDL3
      &
      (TEMP"L.CyclePosition =
        PerformResourceCheck =>
        (LGDL5
        &
        (TEMP"L.CyclePosition =
          AttachDevices =>
            (LGDL6
            &
            LGDL7)))))

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3.3.2 Authorization Process (Formal)

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<< L.CyclePosition =
ReadAccessPassword >>
LGPL4
&
(TEMP"L.CyclePosition =
PerformResourceChecks ->
(LGOL5
&
(TEMP"L.CyclePosition =
AttachDevices ->
(LGOL6
&
LGOL7)))))

<< Error)
<< Error)
<< MsgName(Text) = LineStatus =>
NTIK1
<< Error)
<< Error)
<< (MsgName(Text) = LineStatus =>
NTIK1
<< MsgName(Text) = LineInfo =>
LGOL1
<< Error))
3.3.2 Authorization Process (Formal)

transform MsgNkcp (MsgId: MessageId, Text: String, Source: ProcessName)

refcond Source =: TrustedProcesses | NetworkProcess

effect (E"P;PendingRequest(Px:PendingRequests & P.MsgId = MsgId) =>
E"P;PendingResponse(Px:PendingRequests & P.MsgId = MsgId &
(P.Kind = OpRequest =>
(MsgName(Text) = ResponseToOpRequest =>
ProcessedResponse(P, Text, Source) => Error)
< P, Kind = S" (NewVM, ConnectVM, NewUser, NewOrConnectedVM) =>
(E"L:LineEntry(L:Lines & L.Laddr = Laddr(Text)) =>
LGOL6 => Error)
< P, Kind = RelinquishDevice =>
(MsgName = DetachDevice =>
NKCP6 => Error)
< Error)) =>
< (MsgName(Text) = Disconnect =>
NKCP1 =>
< MsgName(Text) = Logoff =>
NKCP2 =>
< MsgName(Text) = DropUser =>
NKCP3 =>
< MsgName(Text) = Link =>
NKCP4 =>
< MsgName(Text) = DetachDevice =>
NKCP5 =>
< MsgName(Text) = PurgeNkcp =>
NKCP7 =>
< Error))

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transform AuthDriver (InterruptType: ?, InterruptSubType: ?, MsgId: MessageId, Text: String, Source: ProcessName)

effect (InterruptType = ExternalInterrupt =>
(InterruptSubType = Message =>
MessageReceived &
(Source = OpProcess =>
MsgOp(MsgId, Text, Source)
<> Source = UPProcess =>
MsgUR(MsgId, Text, Source)
<> Source = NetworkProcess =>
MsgNet(MsgId, Text, Source)
<> Source <=: TrustedProcesses || NetworkProcess =>
MsgNet(MsgId, Text, Source)
<> Error)
<> Error)
&
KernelCalled(ReceiveInterrupts)
&
KernelCalled(ReleaseCPU)
end AuthProcess
3.4.1: Accounting Process
Informal Description

This section contains the informal description of the Accounting Process of KVM/378.

Overview

The Trusted Process performing the accounting function, ACNTProcess, is one of the simpler processes. It accepts two flavors of accounting records from NKCPs, and saves them in a data base. It also accepts two operator commands that cause the old data base to be saved and a new empty one to be created.

The only complexity is the need for preserving the *-property when tallying the computer usage accounts. Each user is presented with a bill which contains no information derived from other users' accounting information. To accomplish this, the Accounting Process keeps its accounting records keyed on user id.

The formal specification also glosses over an important effect of the operator's commands. In "OPI", the "effect" section says nothing about actually saving the old data base, presumably as a spool file intended for the card punch.
NKCP Communication with the Accounting Process

There are two kinds of message that an NKCP can send to the Accounting Process. Their respective labels are:

- DeviceUse; and
- SystemResourceUse.

The first, DeviceUse, is indirectly sent to the Accounting Process by an NKCP whenever a device is detached from a VM. The accounting record describes the utilization of the device by the VM. The message comes to the Accounting Process via the Authorization Process.

The second message type, SystemResourceUse, is also indirectly sent to the Accounting Process by an NKCP via the Authorization Process. When a VM logs off (or is forced off, etc.), the controlling NKCP notifies the Authorization Process so that system tables may be updated and communication lines freed. As part of this message, the NKCP includes accounting information that the Authorization Process reflects to the Accounting Process.

The design purposely incorporates this roundabout form of message passing so that the user id (VM name) reported in the accounting record may be verified to actually exist as a VM controlled by the requesting NKCP.
Communication between the Operator and the Accounting Process

There are two operator commands which affect the Accounting Process:

- ACNT:
- SHUTDOWN.

The operator command ACNT has the following permissible parameters:

- user id;
- ALL; and
- PUNCH.

The first two are present in VM/370; the last is new in KVM. The first two cause one or more NKCPs to generate accounting records for users. These accounting records are sent as messages to the Authorization Process, which verifies that the user ids are indeed logged on and being controlled by the reporting NKCP. The Authorization Process then sends the messages on to the Accounting Process for recording.

The operator commands ACNT-PUNCH and SHUTDOWN are reflected by the Operator Process directly to the Accounting Process. The commands cause the current data base of accounting records to be saved, and a new empty one to be started. Both have the same effect.
module AcntProcess

type
MessageLabels = (SystemResourceUse, DeviceUse, ACNT-PUNCH, SHUTDOWN),
KernelFunction = (SendMessage),

constant
AuthProcess, OpProcess: ProcessName,
Error: boolean,
SendMessage(ProcessName): KernelFunction

transform KernelCalled(K:KernelFunction)
effect true

/** Parameter Functions **/

countant
MsgName(String): MessageLabels,
User(String): VirtualMachineName,
NewPosting(String): String
type
Char,
String = list of Char,
VirtualMachineName,
ProcessName,
MessageId,
AccountingRecord = structure of
  User = VirtualMachineName,
  Postings = set of String)

variable
Accounting: set of AccountingRecord

initial
Accounting = Empty

invariant
A1,A2:AccountingRecord (A1:<:Accounting
  &
  A2:<:Accounting ->
Subdriver of AcntProcess,

handling messages from AuthProcess

transform MsgAuth(MsgId: MessageId,
  text: String,
  Source: ProcessName)

  refcond Source = AuthProcess

  effect (MsgName(Text) <; String(SystemResourceUse,DeviceUse) =>
    AUTH(User(Text),NewPosting(Text))
  => Error)
Subdriver of AcntProcess, handling messages from OpProcess

transform MsgOp(MsgId: MessageId, Text: String, Source: ProcessName)

refcond Source = OpProcess

effect (MsgName(Text)<>S"(ACNT-PUNCH, SHUTDOWN)" => OP1
  <> Error)
AUTH1: Accounting record from Nkcp via Authorization Process:
System Resource Use or Device Use

transform AUTH1(User: VirtualMachineName,
NewPosting: String)

refcond true /* user id has been validated by AuthProcess
prior to the sending of this message */

effect E"A:AccountingRecord(A:<Accounting ->
(A.User = User
\delta
NewPosting:<A.Postings))

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3.4.2 Accounting Process (Formal)

OP1: Operator command to re-initialize the accounting data base

transform OP1

effect N"Accounting - Empty

&

Kernel Called(SendMessage(OpProcess))
transform AcntDriver (InterruptType:
InterruptSubType:
MsgId; MessageId,
Text: String,
Source: ProcessName)

effect (InterruptType = ExternalInterrupt =>
InterruptSubType = Message =>
(Source = OpProcess =>
    MsgOp(MsgId, Text, Source)
) => Source = AuthProcess =>
    MsgAuth(MsgId, Text, Source)
) => Error)

end AcntProcess
This section contains the informal description of the Updater Process of KVM/370.

Overview

The Updater creates and updates the set of databases which are collectively known as the Directory. The Directory contains information about system users, devices, terminals, and system-owned volumes.

Each user id must be unique within the system. Associated with the user id is a clearance (maximum security-level) and a list of capabilities as well as notes for the use of any NKCP to which the user may be attached.

Each real device and terminal is associated with a security-level which is the maximum level of information that may appear on that device.

KVM extends the concept of system-owned volumes to include not only the system residence volume and those having page/spool space, but also any shared real volume (i.e., any volume containing minidisks). Such a volume must be partitioned in such a way as to prevent overlap.
THE UPDATER REQUESTS

The System Security Officer or other user of the Updater may make the following types of requests:

1. Add, change or delete a user.
   The following are associated with each user:
   - user id (must be unique)
   - password
   - clearance
   - objects (a list of (object-name, access-type)) where
     object-name may name a minidisk or a real device.
   - notes for use by NKCP
   - privilege classes (zero or more of A..H)
   - maximum and default storage sizes
   - virtual devices (a list of (vaddr, devtype, corresponding real device)) (if any)
   - initial scheduling priority
   - initial line editing characters
   - accounting information and output distribution code
   - options (zero or more of ECHOED, REALTIMER, ACCT, SVCOFF, BMK)
   - auto IPL system, if any

When a new user is added to the directory, all the fields must be specified, though some may be defaulted to null (objects, privileges, virtual devices and options) or to standard values (priority = 50, line-edit = [ON,'a','1','#','"']). The user id must be distinct from any user id presently in the directory.

When updating a user entry, any of the above fields may be changed. If the user id is changed, the new value must not be the same as any other user id in the directory. The following are recognized as special cases:

   (a) add or delete a category in clearance
   (b) add or delete an object
   (c) add or delete a privilege to the privilege classes.
   (d) add, delete or change a virtual device.
   (e) the options are not treated as a list. Rather, each is handled as a separate boolean.

Each real device mentioned in the virtual device list must have a corresponding real device mentioned in the links or dedicates section. Each real device and link should have a corresponding entry in the virtual devices, though a failure to do so is not an error and the entry may be stored after confirmation by the System Security Officer (SSO).
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3.5.1 Updater Process (Informal)

3.5.1.1 Updater Process (Informal)

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2. Update the security lattice
   Add a special-access compartment

3. Create, change and delete devices and terminals (lines).
   Each device has the following associated with it:
   - Device address and type
   - Clearance (maximum security level)
   - Minimum security level, if any
   - Flags:
     - Trusted/untrusted device
     - System-owned (i.e., owned volumes and only
       owned volumes may be mounted).

4. Create, format and allocate real System Owned Volumes
   a. Define volume
      - Volume serial number (must be unique)
      - Maximum security-level
   b. Label volume (volume must be mounted and attached to Updater)
      - Volume serial number
      - Real device
      
      sec-level(device) must dominate sec-level(volume) existing
      volume label (if any) (cyl 0, track 0, record 3) is typed out for
      SSO who must confirm that he wants to format the volume.

      A label and blank allocation record (all cylinders except 0
      available) are written on the volume, which is then detached from
      the Updater and attached to "SYSTEM".
THE FOLLOWING REQUIRE THE VOLUME BE MOUNTED AND ATTACHED TO "SYSTEM".

c. Delete volume. The volume is deleted from the owned volume list. All cylinders marked as classified have home addresses written on each track (which clears the rest of the track) and are marked available.

d. Allocate space
   - type of space:
     (Global areas - security level need not be specified - always system-high - volume must be system-high)
     PAGE (suballocated by DASD page allocator)
     SPOOL (cylinders suballocated by Spool File Memory, records by NKCPs)
     Directory
     IPL area
     (areas used by NKCPs - security level must be specified)
     WarmStart or checkpoint area
     Shared segment area
        - name of segment (must be unique)
     Temporary Disk Space (suballocated by NKCP)
     Minidisks
        - name (must be unique)
        - passwords or ACLs
           (ACLs are array by accesstype of [user id])
        - security-level (except global areas which are always system high. The security level of an area must be dominated by the clearance of the volume.)
        - starting cylinder
        - number of cylinders

The requested area must not overlap any area currently allocated on the volume. Thus, to increase the size of an area, the area must be deleted and then re-allocated in the increased area.

When a shared segment area or Minidisk is created, the name must be different from any other object of the same kind in the system.

If passwords are used, 3 passwords are provided for each minidisk: [read password, write password, simultaneous-write password].

If ACLs are used, the following functions are to be provided:
   - Create a "group" ACL
   - Add or delete a user id to an ACL
   - Add or delete an ACL to another ACL
and the following kinds of ACLs are maintained:
- Read access (may read only)
- Write Access (may write, if no other user is using the disk)
- Multiple Access (may write, even though other users are using the disk)
- Control Access (may modify the ACL for this disk)

If audit trails are kept, the first cylinder of each minidisk will be set aside for audit trails and, possibly, ACLs. Hence, the virtual size of the minidisk will be one cylinder smaller than that specified by the SSD.

e. Free space
   - type
   - name

When an existing area is freed, the contents should, in principle, be erased unless the area is being reassigned to the same security level. In addition, no further accesses to the deleted area should be allowed. This latter consideration brings up the problem of capability revocation, see below.

f. Delete space - like 'Free Space' except that the space is made permanently unavailable for allocation and hence need not be cleared until the volume is deleted.
REVOCATION OF CAPABILITIES

One of the problems encountered in capability-based systems is that of revoking a capability after it has been granted and used. When a process has been granted a capability it may have multiple links to the control blocks which represent that capability; in some systems the original grantee may be able, in turn, to grant the capability or some subset to other processes. Further, there may be other capabilities that depend on the original capability to be meaningful. Deleting the original capability without deleting those dependent on it may produce a potential security violation.

There is a denial of service problem which further complicates matters. If the Security Kernel revokes a capability without notice, the process may be unable to continue working. Moving an empty chair won't bother anyone - unless she is starting to sit down in it.

A number of approaches to this problem have been used in KVM. The most general approach is an extension of that used in VM/370 - currently granted capabilities are never revoked. If, while a user is logged on, a new directory is created in which his privileges are changed, the changes do not take effect until he logs off (thus releasing his current capabilities) and logs back on. If the changed privilege is access to a minidisk, he can also get the new privilege by detaching the virtual device (thus releasing the capability) and relinking to it (thus getting the new capability). Similarly, in KVM the Initiator will be consulted only when a user logs on to the system or attempts to link to a disk or have a device attached. As long as he is using it, changes to the security database (the Directory) will not affect him.

Another approach is to refuse to delete capabilities unless all dependent capabilities have also been deleted. For example, the Kernel will execute the Destroy VM call only if all page frames, page slots and address spaces belonging to the subject VM have first been detached or destroyed. Similarly, an NKCP (process) can be destroyed only if it has no outstanding requests which can cause completion signals to be sent to the non-existent process. A page frame may not be released by a process if the process has pending I/O involving that page frame.

Another approach involves the management of equivalent capabilities. In a paging system, for example, all page frames and page slots are equivalent to each other outside of the paging management module. Thus, the Kernel can safely move virtual pages between main memory and DASD without notice to the processes. The Kernel must, however, respect certain critical regions within NKCPs when the status of a page is expected to remain constant. This problem is discussed more completely in other papers.
The approach used in managing the Directory is a mixture of several. Thus, user ids and their access rights can be freely changed in the Directory without interacting with current use of those rights. The changes will take effect when the user releases his current use of the capability. Allocation of space on disk volumes is a slightly different problem, however. If a minidisk is deleted and the space reassigned while a process is using it, another process may get access to the reassigned space, resulting in two processes with read-write access to the same disk area—a clear violation of KVII's security policy.

To avoid such a violation, we forbid deletion of DASD space while a process is using it. If the SSO requests that an area be freed or deleted, the Updater will send a message to the Initator requesting permission to do so. The Initator will reply OK if the area is not currently in use, otherwise NO. In either case, the Initator will mark the area as unavailable for use so that no process will be granted use of it while the SSO is updating the directory. When the SSO finishes updating the directory, a new copy is created and the Updater notifies the Initator to use the new copy for all future requests. Upon receipt of that message, the Initator will read in the new directory, which will result in all 'unavailable' marks being released.

Finally, in order to allow the SSO to conveniently do his work in the face of the possibility of having a request denied because the named area is in use, we add the following requests:
5. Create and replace directories

a. Create new directory - when the SSO is satisfied with the changes he has made, he can cause the new directory to be built and installed. If he has changed the security level of an area, he will be required to confirm his desire to erase, up- or downgrade the contents of that area.

b. Reuse old directory - when the SSO has begun a series of directory changes but is unable to complete them due to denial of a request or a typing error, he can request that the old directory be re-installed. This sends a message to the Initiator causing it to forget all its 'not available' marks and continue using the old directory.

c. Start over - if the SSO has a problem with the series of directory changes he is making, but doesn't want to release the 'not available' marks on his relation requests, he can request the Updater to start over with a fresh copy of the old directory for him to update, in effect 'forgetting' all changes he has made while preventing any access to areas he wants to reassign.

Note that if the area is in use, the SSO's request will be denied, but 'not available' flags will still be set, so that the area will eventually, as processes log off, be available for freeing.
module UpdaterProcess
  type
    Char,
    String = list of Char,
    DeviceAddress,
    LineAddress,
    Volumeld,
    ProcessName,
    VirtualMachineName,
    DeviceTypes = (Reader, Printer, Punch, TapeDrive, NonsharableDisk)
  constant
    Dominates(ProcessName, ProcessName): boolean,
    DeviceType(DeviceAddress): DeviceTypes,
    #MaxCylinders: integer,
    #Cylinders(Volumeld): integer
type
AccessModes = (Read, Write),

PossibleEntries = (Paging, Spooling, Minidisk, Unknown, System).

CylInt = 1""!: integer(1 <= i & i <= #MaxCylinders),

DirectoryEntry = structure of {
    VmId = VirtualMachineName,
    LogonPassword = String,
    DialPassword = String,
    LinkPassword = String,
    MaxSecLevel = ProcessName,
    MinSecLevel = ProcessName,
    DedicatedDevices = set of DedicatedDeviceEntry,
    Links = set of MDLinkEntry,
    InDefined = boolean,
    AccessPasswords = set of AccessPasswordEntry),

LineEntry = structure of {
    Laddr = LineAddress,
    MinSecLevel = ProcessName,
    MaxSecLevel = ProcessName),

AccessPasswordEntry = structure of {
    SecLevel = ProcessName,
    Password = String),

DedicatedDeviceEntry = structure of {
    Daddr = DeviceAddress,
    VolSecLevel = ProcessName,
    Access = set of AccessModes),

MDLinkEntry = structure of {
    MName = MinidiskName,
    Access = set of AccessModes),

URPOwnedDeviceEntry = structure of {
    Raddr = DeviceAddress,
    MaxSecLevel = ProcessName,
    MinSecLevel = ProcessName),

NonshareableDriveEntry = structure of {
    Raddr = DeviceAddress,
    MaxSecLevel = ProcessName,
    MinSecLevel = ProcessName),

SharableDriveEntry = structure of {
    Raddr = DeviceAddress,
    SecLevel = ProcessName),

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SharedVolumeEntry = structure of (  
Volume = VolumeId,  
SecLevel = ProcessName,  
Map = set of CylMap),

CylMap = structure of (  
Cylinders = CylInt >< CylInt,  
Category = PossibleEntries),

MiniDiskEntry = structure of (  
MOName = MiniDiskName,  
ContainingVolume = VolumeId,  
Cylinders = CylInt >< CylInt,  
SecLevel = ProcessName,  
AccessControlList = set of ACLEntry),

ACLEntry = structure of (  
User = VirtualMachineName,  
Access = set of AccessModes)
variable
URPOwnedDevices: set of URPOwnedDeviceEntry,
NonsharableDrives: set of NonsharableDriveEntry,
SharableDrives: set of SharableDriveEntry,
SharedVolumes: set of SharedVolumeEntry,
MiniDisks: set of MiniDiskEntry,
Lines: set of LineEntry,
UserDirectory: set of DirectoryEntry
transform Updater Process

effect DistinctDeviceAddresses
& LegalUserDirectory
& LegalLines
& LegalMiniDisks
& LegalSharedVolumes
& LegalSharableDrives
& LegalNonSharableDrives
& LegalURPOwnedDevices
DistinctDeviceAddresses =

A"U:URPOwnedDeviceEntry(U:<URPOwnedDevices ->
   (A"NS:NonshareableDriveEntry(NS:<NonshareableDrives ->
      (U.Raddr = NS.Raddr)))
      &
   A"S:ShareableDriveEntry(S:<ShareableDrives ->
      (U.Raddr = S.Raddr))))
      &
A"NS:NonshareableDriveEntry(NS:<NonshareableDrives ->
   A"S:ShareableDriveEntry(S:<ShareableDrives ->
   NS.Raddr = S.Raddr))
   ,
LegalUserDirectory =
  A"U1,U2:DirectoryEntry(U1:<UserDirectory &
    U2:<UserDirectory ->
    (U1,UserId = U2,UserId -> U1 = U2)) &
  A"U:DirectoryEntry(U:<UserDirectory ->
    (NomInates(U,MaxSecLevel,U,MinSecLevel)) &
    LegalDedicatedDevices(U) &
    LegalLinks(U) &
    LegalAccessPasswords(U)))
LegalDedicatedDevices(U:DirectoryEntry) =

A"E1,E2:DedicatedDeviceEntry(E1:<U.DedicatedDevices &
E2:<U.DedicatedDevices ->
(E1.Raddr = E2.Raddr -> E1 = E2))
&
A"E:DedicatedDeviceEntry(E:<U.DedicatedDevices ->
E"D:URPOwnedDeviceEntry(O:<URPOwnedDevices &
O.Raddr = E.Raddr &
(DeviceType(E.Raddr) = Reader ->
(E.VolSecLevel = nil &
E.Access = S"(Read)) &
(DeviceType(E.Raddr) = S"(Printer, Punch) ->
(E.VolSecLevel = nil &
E.Access = S"(Write)) &
(DeviceType(Raddr) = TapeDrive ->
(Dominates(O.MaxSecLevel,E.VolSecLevel) &
Dominates(E.VolSecLevel,O.MinSecLevel) &
Dominates(U.MaxSecLevel,E.VolSecLevel) &
~Empty(E.Access)))))
&

xor
E"D:NonsharableDeviceEntry(O:<NonsharableDrives &
O.Raddr = E.Raddr &
Dominates(O.MaxSecLevel,E.VolSecLevel) &
Dominates(E.VolSecLevel,O.MinSecLevel) &
Dominates(U.MaxSecLevel,E.VolSecLevel) &
~Empty(E.Access))))
&
A"L1,L2:MDL LinkEntry(L1:<U.Links
   &
   L2:<U.Links ->
   (L1.MDName = L2.MDName -> L1 = L2))
&
A"L:MDL LinkEntry(L:<U.Links ->
E"M:Mini DiskEntry(M:<MiniDisks &
   (M.MDName = L.MDName
   &
   E"A:ACLEntry(A:<M.AccessControlList &
      (A.User = U.UserId
      &
      A"AM:Access Modes(AM:<L.Access ->
      AM:<A.Access))
   &
   Dominates(U.MaxSecLevel,M.SecLevel)))
&
~Empty(L.Access))
LegalAccessPasswords(U:DirectoryEntry) =
        &
        A2::U.AccessPasswords)
        ->
        (A1.SecLevel = A2.SecLevel -> A1 = A2))
    &
        ->
        (Dominates(U.MaxSecLevel,A.SecLevel)
            &
            Dominates(A.SecLevel,U.MinSecLevel)))
LegalLines =
A"L1,L2:LineEntry(L1<:Lines
&
L2<:Lines ->
(L1.Laddr = L2.Laddr -> L1 = L2))
&
A"L:LineEntry(L<:Lines ->
Dominates(L.MaxSecLevel,L.MinSecLevel))
LegalMiniDisks =
A"M1,M2:MiniDiskEntry(M1<:MiniDisks
 &
 M2<:MiniDisks ->
 (M1.MDName = M2.MDName -> M1 = M2))
 &
A"M:MiniDiskEntry(M<:MiniDisks ->
 (LegalContainingVolume(M)
 &
 M.Cylinders.1 < M.Cylinders.2
 &
 M.Cylinders.2 <=#Cylinders(M.ContainsVolume)
 &
 M.Cylinders.1 < #Cylinders(M.ContainsVolume)
 &
 LegalAccessControlList(M)))
LegalContainingVolume(M:MiniDiskEntry) =
E"S:SharedVolumeEntry(S:SharedVolumes &
(S.Volume = M.ContainingVolume)
&
Dominates(S.SecLevel,M.SecLevel))
LegalAccessControlList(M:MiniDiskEntry) =
  A"A1,A2:ACLEntry(A1<M.AccessControlList
   &
   A2<M.AccessControlList ->
   &
  A"A:ACLEntry(A<M.AccessControlList ->
   (E"D:DirectoryEntry(D<UserDirectory &
   (D.UserId = A.User))
   &
   ~Empty(A.Access))))
LegalSharedVolumes =

A*S1,S2:SharedVolumeEntry(S1<:SharedVolumes & S2<:SharedVolumes -> (S1.Volume = S2.Volume -> S1 = S2)) &
A*S:SharedVolumeEntry(S<:SharedVolumes -> (LegalMap(S)))
LegalMap(SharedVolumeEntry) =

/* non-overlap */
A"M1,M2:Map(M1:<S.Map
    &
    M2:<S.Map ->
    (M1.Cylinders.1 > M2.Cylinders.2
    | M1.Cylinders.2 < M2.Cylinders.1))
&
A"M:Map(M:<S.Map ->
    (/* each entry non-empty */
    M.Cylinders.2 > M.Cylinders.1
    &
    /* no cylinders unaccounted for */
    M.Cylinders.2 = #Cylinders(S.Volume) ->
    E"M1:Map(M1:<S.Maps &
    M1.Cylinders.1 = M.Cylinders.2 + 1)))
&
E"M:Map(M:<S.Map &
    (M.Cylinders.1 = 1))
&
/* each MiniDisk actually logged */
A"M:Map(M:<S.Map ->
    (M.Category = MiniDisk ->
    E"MD:MiniDiskEntry(MD:<MDs &
    (MD.ContainingVolume = S.Volume
    &
    MD.Cylinders = M.Cylinders))))
LegalSharableDrives =
   A"SD1,SD2:SharableDriveEntry(SD1:<;SharableDrives
   &
   SD2:<;SharableDrives ->
   (SD1.Raddr = SD2.Raddr -> SD1 = SD2))
LegalNonshareableDrives =
A"NS1,NS2:NonshareableDriveEntry (NS1:NshareableDrives
  &
  NS2:NshareableDrives ->
  (NS1.Raddr = NS2.Raddr -> NS1 = :NS2))
&
A"NS:NonshareableDriveEntry (NS:NshareableDrives ->
  Dominates (NS.MaxSecLevel, NS.MinSecLevel))
LegalURPOwnedDevices =

A"U1.U2:URPOwnedDeviceEntry(U1:<:URPOwnedDevices
&
U2:<:URPOwnedDevices ->
(U1.Raddr = U2.Raddr -> U1 = U2))
&
A"U:URPOwnedDeviceEntry(U:<:URPOwnedDevices ->
(Dominates(U.MaxSecLevel,U.MinSecLevel))
&
DeviceType(Raddr) <:S" (Reader, Printer, Punch, TapeDrive))

end UpdaterProcess