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FORMAL SPECIFICATIONS OF KVM/370 KERNEL AND TRUSTED PROCESSES

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21 MAY 1978

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DIRECTORATE FOR FREEDOM OF INFORMATION
AND SECURITY REVIEW (OASD-PA)
DEPARTMENT OF DEFENSE

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Contract MDA903-76-C-0260

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Introduction

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INTRODUCTION

This document contains the formal specification of the kernel and trusted processes of the Kernelized VM operating system (KVM/370). The specification utilizes the specification language INA JO, a proprietary product of System Development Corporation. INA JO is described in TM-6021/000/00, 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/370", TM-5855/200/00, 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.

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2.1 KVM Security Policy

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2.1: KVM Security Policy

This section describes the security policy implemented by KVM/370. 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.

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2.1 KVM Security Policy

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specification KVM-Security-Kernel

module TopLevel

/* Definition of Security Level and related Functions */

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

constant LowLevel = L"H:HierarchyLvl(A"J:HierarchyLvl(H <= J)).1 /*Unclassified*/,
HighLevel = L"H:HierarchyLvl(A"J:HierarchyLvl(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) |
/* "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,

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2.1 KVM Security Policy

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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 */

2.2: Machine Specifications

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 (DAT) Structures */

type Byte
type PageOfBytes = T"L: list of Bytes (C"L = PageSize*1024)

/* real page frame address >< validity */
type PageTableEntry = VPage >< boolean

/* For data structure purposes, page tables are thought of as containing the addresses of the pages they refer to, and segment tables as containing the page tables */
type PTEList = list of PageTableEntry.
PageTable = T"P: PTEList (C"P = PagesPerSegment),
SegmentTableEntry = PageTable >< boolean,
STEList = list of SegmentTableEntry

/* storage keys */
type ProtectionKey.
KeyInStorage = structure of
(Key = ProtectionKey,
NoFetch = boolean,
Refer = boolean, Change = boolean)
constant Key0: ProtectionKey

/* Addressing Technique */
type VPage = T"I: integer (0 <= I < 16*1024/PageSize),
ByteOffset = T"I: integer (0 <= I < PageSize*1024),
Address370 = VPage >< ByteOffset

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2.3 Paging Parameters

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2.3: Paging Parameters

This section defines the parameters and data types controlling paging and address space manipulations.

```
/* paging system constants */
constant PageSize = 2 /*2K=2048*/ , SegmentSize = 64 /*64K=65536*/ ,
    PagesPerSegment = SegmentSize/PageSize /*32*/ ,
    PageTableEntrySize = 2 /*Halfword=2 bytes*/ , PageTableHeaderSize = 8,
    SegmentTableEntrySize = 4, SegmentTableHeaderSize = 0,
    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 ( 1 >= 0)
type Status = (NKCPData, Free, EmptyPage, ReadOnly, ReadWrite, IN, OUT)
type PageFrameName, PageSlotName, SlotAddress, AddressSpaceDesignator

constant P0: PageFrameName /* "name" of an NKCP's page 0 */

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,
    VirtAddr = VirtualPage, Contents = PageOfBytes),
    PageSlot = structure of
    (Addr = SlotAddress,
    Status = T"(Free, EmptyPage, ReadOnly, ReadWrite),
    /* 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
    (VMname = VirtualMachineName,
    A = AddressSpaceDesignator,
    Vaddr = VPage),
    VirtualPage = structure of
    (Status = T"(ReadOnly, ReadWrite, EmptyPage),
    /* following fields meaningful only if Status == EmptyPage */
```

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2.3 Paging Parameters

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VSlot = PageSlotName,
SavedKey = KeyInStorage, Refer = boolean, Change = boolean,
Contents = PageOfBytes,
Valid = boolean,
/* following meaningful only if Valid = true */
Raddr = VPage /* 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.VirtAddr.Valid -> P1.VirtAddr.Raddr = P1.Addr)
 & ((P1.Addr = P2.Addr |
 P1.Owner = P2.Owner & P1.VirtualName = P2.VirtualName
 & P1.Status == Free & P2.Status == Free
 | P1.VirtAddr.Valid & P2.VirtAddr.Valid & E"V: VirtualPageName
 (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)

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2.4 Legality Checking Macros

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2.4: Legality Checking Macros

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)
```

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2.5

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Address Space Definition and Functions

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2.5: Address Space Definitions and Functions

This section describes virtual address spaces and the functions that create and destroy them.

```
/* 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 <= 16*1024/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<:S.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<: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))
```

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2.5 Address Space Definition and Functions TM-6062/101/00

```
transform CreateAddressSpace (VM: VirtualMachineName,  
                              Size: VPage,  
                              A: AddressSpaceDesignator,  
                              R: KProcBlok)  
  
refcond R<:ProcessList & R.Proctype = NKCP  
      & VM ~- SYSTEM & CheckVM(R, VM)  
      & ~AddressSpace(K,A).Exists  
  
effect ( AreaOK(R.ProcName, (SegmentTableHeaderSize +  
                              RoundSegments(Size) *  
                                (SegmentTableEntrySize  
                                + PageTableSize + SwapTableSize)))  
      => ReturnCode(R,0)  
      & E"S:ASpace (N"AddressSpace(K,A) = S &  
        NullSpace(S) & S.NumberOfPages = Size  
        & N"Spaces = Spaces || S" (S)  
        & AdjustQuota(R.ProcName,  
          SegmentTableHeaderSize  
        + RoundSegments(Size) *  
          (SegmentTableEntrySize  
          + PageTableSize + SwapTableSize) ) )  
      <> ReturnCode(R,1) & N"Spaces = Spaces  
        & N"K = K & AdjustQuota(R.ProcName,0) )
```


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2.5

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Address Space Definition and Functions

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transform Destroy AddressSpace(VM: VirtualMachineName,
A: AddressSpaceDesignator,
R: KPProcBlok)

refcond R:ProcList & R.ProcType = NKCP
& CheckSpace(R, VM, A)
& NullSpace(AS)

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

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2.6 Create/Destroy Process

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2.6: Create/Destroy Process

This section describes KVM'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,  
     ClockCompInterruptPending = boolean,  
     TrackingQuantum = boolean,  
     QuantumEnded = boolean,  
     CPUTimerInterruptPending = boolean,  
     RemainingQuantum = SignedDoubleword, CPUtimer = SignedDoubleword,  
     IntvlTimer = integer, IntvlTimerInterruptPending = boolean,  
     Internals = IntState,  
     AddressSpace = ASpace)
```

```
variable ProcessList: set of KProcBlok
```

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2.6 Create/Destroy Process

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```
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"l: 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 ( ~SlotsOK (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"P:KProcBlok, S:ASpace, PF:PageFrame (N"Spaces = Spaces ↑↑ S" (S)
& S.NumberOfPages = ASize
& N"ProcessList = ProcessList || S" (P) & P.ProcName = Process
& PF.Owner = INITIATOR & PF.VirtualName = Page0
& N"PF.Owner = Process
& N"PF.VirtualName = P0 /* PageFrameName Constant */
& P.AddressSpace = S & NoInterruptsPending(P)
& S.PurgeTLBneeded
& A"l:VPage ( (I<=CSize -> RealAddress(S,I).2
      & E"PF:PageFrame
(PF.Owner = Initiator & PF.VirtualName = (Code;Page0).(I+1)
& PF.Addr = RealAddress(S,I).1 )
      & (I > CSize & I < ASize ->
      ~RealAddress(S,I).2))))))
```

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2.6 Create/Destroy Process

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transform DestroyProcess(Process: ProcessName,
R: KProcBlok)

refcond R.ProcName = INITIATOR & R<:ProcessList
& LET "P" = U"P: KProcBlok (P<:ProcessList & P.ProcName = Process)
& 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)
& AdjustQuota(INITIATOR, - (KProcBlokSize
+ASpaceSize(S.NumberOfPages))))
<> ReturnCode(R,1))

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2.7 Create/Destroy VM

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2.7: Create/Destroy VM

This section describes KVM's virtual machines and the functions that create and destroy them.

```
type VirtualMachineName,  
    KVMblock = structure of  
        (VMname = VirtualMachineName, Owner = ProcessName)
```

```
constant SYSTEM: VirtualMachineName  
variable KVMTable: set of KVMblock
```

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2.7 Create/Destroy VM

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transform CreateVM(VM: VirtualMachineName,
NCKPName: ProcessName,
R: KProcBlok)

raifcond R.ProcName = INITIATOR
& El"P: KProcBlok (P<:ProcessList & P.ProcName = NKCPName
& P.ProcType = NKCP)

effect (E"K:KVMblok (K<:KVMtable & K.VMName = VM)
=> ReturnCode(R,1)
<> A"K:KVMblok (K<:KVMtable -> K.VMName ~ VM)
=> El"K:KVMblok (K.VMName = VM & K.Owner = NKCPName
& A"A:AddressSpaceDesignator(
~AddressSpace(K,A).Exists)
& N"KVMTable = KVMTable || S"(K)))

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2.7 Create/Destroy VM

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transform DestroyVM (VM:VirtualMachineName,
R: KProcBlok)

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)

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2.8 Grant/Revoke Functions

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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.

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

type ObjectName = structure of
   (KindOfObject = (SharedSegment, HorizontalMinidisk,
                   VerticalMinidisk, WholeDevice),
    /* Pages meaningful only if KindOfObject = SharedSegment,
       Vol only if KindOfObject = Horizontal or VerticalMinidisk
       Slice only if KindOfObject = HorizontalMinidisk,
       Start and Finis only if KindOfObject = VerticalMinidisk,
       Dev only if KindOfObject = WholeDevice */
    Pages = list of PageFrameName,
    Vol = RealVolumeld,
    Slice = HeadNumber,
    Start = CylinderNumber,
    Finis = CylinderNumber,
    Dev = DeviceAddress)
constant NullDevice: DeviceAddress
type OwnedVolume = structure of
   (Name = RealVolumeld,
    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: RealVolumeld) ==
   LET"VOL = U"VOL: OwnedVolume (
      VOL.Name = V & VOL <: OwnedList)
   & VOL.Device == NoDevice
```


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2.8 Grant/Revoke Functions

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```
type Grant = structure of
  (Access = set of (ReadOnly, ReadWrite),
   Class = (DASD, Terminal, Tape, UnitRecord),
   Dedicate = boolean,
   /* following meaningful only if Class = DASD.
      Tracks meaningful only if Horizontal = true,
      Cyls only if Vertical = true
   Horizontal = boolean,
   Vertical = boolean,
   Tracks = set of HeadNumber >< Access,
   Cyls = set of CylinderNumber >< Access )
  */
constant NoAccess: Grant
```

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2.8 Grant/Revoke Functions

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```
transform GrantAccess(Object: ObjectName,  
                      Acc: (ReadOnly, ReadWrite),  
                      P:  
                      KProcBlok)
```

```
refcond TRUSTED(R.ProcNAME) & R<:ProcessList & P<:ProcessList  
& (Object.KindOfObject = SharedSegment =>  
  R.ProcName = INITIATOR  
  & C"Object.Pages = PagesPerSegment  
  & A"Pframe: PageFrameName (Pframe<:Object.Pages  
    -> CheckFrame(R, Pframe)  
    & PF.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 => E1"PT: PageTable  
  (PT<:N"SharedSegmentList  
  & A"i: Integer (i > 0 & i <= PagesPerSegment  
    -> CheckFrame(R, Object.Pages.i)  
    & PT.i = PF)  
  & PT<:N"SharedSegmentList(P)  
  & PT.Name = Object.Name)  
<> Object.KindOfObject = WholeDevice =>  
  LET"G = GrantedAccess(P.ProcName, Object.Dev)  
  & N"G.Access = G.Access || S"(Acc)  
  & N"G.Dedicate = true  
  & N"G.Class = Devtype(Object.Dev).Class  
<> VolumeMounted(Object.Vol)  
  & LET"G = GrantedAccess(P.ProcName, VOL.Device)  
  & N"G.Access = G.Access || S"(Acc)  
  & N"G.Class = DASD & ~N"G.Dedicate  
  & (Object.KindOfObject = HorizontalMinidisk =>  
    N"G.Horizontal & ~N"G.Vertical  
    & N"G.Tracks = G.Tracks || S"(Object.Slice, Acc)  
  Object.KindOfObject = VerticalMinidisk =>  
    N"G.Vertical & ~N"G.Horizontal  
    & N"G.Cyls = G.Cyls ||  
    S"Z: CylinderNumber >< (ReadOnly, ReadWrite)  
    (Z.1 >= Start & Z.1 <= Finis  
    & Z.2 = Acc) ))
```

21 May 1978
2.8 Grant/Revoke Functions

System Development Corporation
TM-6062/101/00

transform ReleaseDevice(Device: DeviceAddress,
P,
R: KProcBlok)

refcond R.ProcType = Trusted
& GrantedAccess (P.ProcName, Device) == NoAccess
& A"LB: LockedBox (LB<:LockedBoxList
& LB.Notify = P.ProcName -> LB.Dev == Device)

effect N"GrantedAccess(P.ProcName, Device) = NoAccess

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2.9 Attach/Detach Page Functions

System Development Corporation

TN-6062/101/00

2.9: Attach/Detach Page Functions

This section defines the functions which place and remove virtual pages in virtual address spaces.

transform AttachPage(Pframe: PageFrameName,
Addr: VirtualPageName
R: KProcBlok)

refcond CheckFrame(R, Pframe)
 & CheckMPage(R, Addr.VMname, Addr.A, Addr.Vaddr)
 & LET VP = VirtPage(A,Addr.Vaddr) & .ET Ad = RealAddress(A,Addr.Vaddr)
 & PF.ILOCK = 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 || S"(Addr)
 & N"VP.Valid

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2.9

Attach/Detach Page Functions

System Development Corporation

TM-5862/101/00

transform DetachPage(Addr: VirtualPageName,
R: KProcBlok)

refcond CheckASpace(R,Addr.VMname,Addr.A)
& LET AD = RealAddress(A,Addr.Vaddr)
& AD.2

effect N"A.PurgeTLBNeeded & ~N"AD.2
& N"VP.VirtList = VP.VirtList ~ S"(Addr)
& (N"VP.VirtList = empty -> ~N"VP.Valid)

21 May 1978
2.10 Swapping Functions

System Development Corporation
TM-5862/101/00

2.10: Swapping Functions

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-5855/200/00. This function is a common routine used by SwapIn and SwapOut. It enters swap requests into the queue of outstanding IO requests.

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

constant Clear, Nochecks: SwapCheck, NullSwap: SwapBlok
  RecNum(SlotAddress), TrackAddress(SlotAddress): integer

variable SwapQueue: set of SwapReq

Invariant A"SR: SwapReq((SR<:SwapQueue
  -> A"B: SwapBlok (B<:SR -> B.Slot.1 = SR.1.Slot.1))
  & A"T: SwapReq (T<:SwapQueue
    & T.1.Slot.1 = SR.1.Slot.1 -> T = SR))
```

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2.18 Swapping Functions

System Development Corporation
TM-6062/101/00

```
transform EnqueueSwap(PF: PageFrame,  
                      Direction: (IN,OUT)  
                      Slot: PageSlot,  
                      Chk: SwapCheck,  
                      Notify: KProcBlok,  
                      ID: RequestName)  
  
refcond PF.ILOCK = 0 & PF.OLLOCK = 0 & ~PF.ULOCK  
      & PF.Intransit<:S" (Free,Direction)  
  
effect (Direction = OUT => SetSlot(PF,Slot) )  
      & N"PF.Intransit = Direction  
      & E"SR: SwapReq, 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.IOLInterruptPending  
  & E"I: IOIntBlok (I<:N"Notify.IOLInterrupts & I.ID = ID)  
  & (Direction = OUT => N"Slot  
      <> N"PF).Status = ReadWrite
```

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2.10 Swapping Functions

System Development Corporation
TM-6062/101/80

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

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

effect E"PS:PageSlot (PS.Status = Free & EnqueueSwap(PF, OUT, PS,
(RecNum(PS.Addr) = 1 => (SearchHAEq, PS.Addr, '
<> (SearchKeyEQ, U"PS1: PageSlot
(PS1<:ReadSlots
& TrackAddr(PS1.Addr) = TrackAddr(PS.Addr)
& RecNum(PS1.Addr) =
RecNum(PS.Addr)-1).Key,
8)),
R, ID))

21 May 1978
2.10 Swapping Functions

System Development Corporation
TM-6062/101/00

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

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

effect EnqueueSwap(PF, IN, PS,
(SearchKeyEQ, PS.Key, 8),
R, ID)

21 May 1978
2.11 Status Page Function

System Development Corporation
TM-6062/101/00

2.11: Status Page Function

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: KProcBlok)  
  
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 (AD.2 => N"VP.Change = (VP.Change I PF.Change)  
        & N"VP.Refer = (VP.Refer I PF.Refer)  
        & N"Status.ReadWrite = (PF.Status = ReadWrite)  
        & N"Status.Present = true  
        <> ~AD.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
```

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2.12 Storage Key Functions

System Development Corporation
TM-6062/101/00

2.12: Storage Key Functions

This section contains the kernel functions that read and write storage keys in virtual pages.

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

```
refcond R.Proctype = NKCP & R<:ProcessList & CheckMPage(R, VM, 0, Page)  
      & LET"VP = VintPage(AS, Page)  
      & LET"Ad = RealAddress(AS, Page) & VP.Status = ReadWrite
```

```
effect N"VP.SavedKey = Key  
      & (Ad.2 => LET"PF = U"PF: 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)
```

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2.12 Storage Key Functions

System Development Corporation

TM-6062/101/00

```
transform ReadStorageKey(VM: VirtualMachineName,  
                        Page: 0..8191,  
                        R: KProcBlok,  
                        Key: KeyInStorage /* output */ )  
  
refcond R.Proctype = NKCP & R<:ProcessList & CheckMPage(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 I VPChange)  
      & N"Key.Refer = (PF.RealKey.Refer I VP.Refer)  
      <> ~RealAddress(A,Page).Valid => N"Key = VirtPage(A,Page).SavedKey)
```

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2.13 Lock/Unlock Page Functions

System Development Corporation

TM-6062/101/00

2.13: Lock/Unlock Page Functions

This section contains the kernel functions that manipulate user locks on page frames.

transform LockPage(Pframe: PageFrameName,
R: KProcBlok)

refcond CheckFrame(R, Pframe) & PF.ILOCK = 0 & ~PF.ULOCK

effect N"PF.ULOCK = true

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2.13 Lock/Unlock Page Functions

System Development Corporation

TM-6062/101/00

transform UnlockPage (Pframe: PageFrameName,
R: KProcBlock)

refcond CheckFrame (R, Pframe) & PF.ULOCK

effect N"PF.ULOCK = false

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2.14 Scheduling Functions

System Development Corporation
TM-6062/101/00

2.14: Scheduling Functions

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.

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

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2.14 Scheduling Functions

System Development Corporation
TM-6062/101/00

transform ResumeProcess(NewPSW: ProgramStatusWord,
Gregs: RegisterSet,
MON: MonitorClasses,
R: KProcBlok)

refcond R:ProcessList

effect N"SYSTEM-Gregs = Gregs
& N"SYSTEM-PSW = NewPSW
& N"SYSTEM-Cregs =
 ((K2, K64), R.AddressSpace.Addresses,
 -1, 0, 0, 0,
 (false /w/w/, 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)

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2.14 Scheduling Functions

System Development Corporation
TM-6062/101/00

transform RECEIVEInterrupts(M: InterruptMask,
R: KProcBlok)

refcond R<:ProcessList

effect (R.IntvTimerInterruptPending & M.IntvTimer
=> SimulateExternalInterrupt(R, X'80')
<> R.MessagePending & M.Message & ~R.MessagePendingReceived
=> SimulateExternalInterrupt(R, X'1202')
<> R.ClockCompInterruptPending & M.ClockComp
=> SimulateExternalInterrupt(R, X'1004')
<> R.CPUTimerInterruptPending & M.CPUTimer
=> SimulateExternalInterrupt(R, X'1005')
<> R.IOInterrupts == empty & M.IO
=> El"B:IOIntBlok (N"R.IOInterrupts = R.IOInterrupts ~ S"(B)
& SimulateIOInterrupt(R, B.ReqType, B.Id))
<> N"R = R)

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2.14 Scheduling Functions

System Development Corporation
TM-6062/101/00

transform ReleaseCPU(R: KProcBlok)

refcond R<:ProcessList

```
effect N"R.Gregs = SYSTEM-Gregs
    & N"R.MON = SYSTEM-Cregs.8
    & N"R.IntvTimer = SYSTEM-TIMER
    & N"R.CPUTimer = SYSTEM-CPUTimer
        + (R.TrackingQuantum => R.CPUTimer - R.RemainingQuantum
            <> 0)
    & E1"P: KProcBlok (P<:ProcessList & N"Requester = P.ProcName
        & ResumeProcess(P, P.ResumePaw, P.Gregs, P.MON)
        & N"SYSTEM-TIMER = P.IntvTimer
        & N"SYSTEM-CPUTimer =
            (P.TrackingQuantum => P.RemainingQuantum
                <> P.CPUTimer) )
    & PurifySharedSystems
```

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2.14 Scheduling Functions

System Development Corporation
TM-6862/101/00

```
transform ScheduleProcess(P, R: KProcBlok)
refcond P<:ProcessList & R<:ProcessList & R.ProcName = SCHEDULER
effect N"Requester = P.ProcName & ResumeProcess(P, P.ResumePsw, P.Cregs, P.MON)
      & N"SYSTEM-TIMER = P.IntvlTimer
      & N"SYSTEM-CPUTimer = (P.TrackingQuantum => P.RemainingQuantum
                           <> P.CPUTimer)
```

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2.14 Scheduling Functions

System Development Corporation
TM-6062/101/00

```
transform DispatchVM(VMname: VirtualMachineName,  
    A: AddressSpaceDesignator,  
    NewPsw: ProgramStatusWord,  
    Gregs: RegisterSet,  
    Fregs: FregSet,  
    DAT: DATSpec,  
    MON: HalfMask,  
    PER: PerSpec,  
    VMA: VMASpec, /* AssistE, VProbSt, ISKd,  
                  370d, SVCd, ShadowE, [CPAsstD,  
                  TimerE, Cregs, VIP*/  
    Time: integer,  
    R: KProcBlok)  
  
refcond R<:ProcessList & R.ProcType = NKCP  
    & Time > 0 & Time < MaxTimeSlice*300*256  
  
effect N"SYSTEM+Gregs = Gregs & N"SYSTEM+Fregs = Fregs  
    & N"SYSTEM-TIMER = Time  
    & N"SYSTEM-PSW = (NewPsw.ProtectionKey,  
                      NewPsw.CC, NewPsw.ILC,  
                      NewPsw.ProgMask,  
                      NewPsw.InstAddr)  
    /* 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 >< MICBlokAddress  
                        (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, true, false, false, false, false),  
                        512)  
    /* RealSegmentTbl, VirtCregs, VIP, VirtPSW,  
    WorkArea, VTimer, 0, 0, 0 */  
    & N"KERNEL+MICBLOK = (AS.Addresses, VMA.8.real, VMA.9, NewPsw, Workarea,  
                        (~VMA.7 => 0  
                        <> Page0Present(AS) => RealAddress(AS,0)+80  
                        <> RealAddress(R.AddressSpace, VMblock).VMTIMER),  
                        0, 0, 0)  
    & CheckASpace(R, VMname, A)
```

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2.15 Allocation Functions

System Development Corporation
TM-6062/101/00

2.15: Allocation/Deallocation Functions

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,

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(U"P: KProcBlok (P.ProcName = PF.Owner),
VPN.VMname,
VPN.A)
& N"AS.PurgeTLBNeeded)

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2.15 Allocation Functions

System Development Corporation
TM-6062/101/00

transform FreeSlot(Slot: PageSlot)
recond Slot.Status ~<:S" (Free, EmptyPage)
effect N"Slot.Status = Free

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2.15 Allocation Functions

System Development Corporation
TM-6862/101/88

transform ReleaseSlot(Slot: PageSlot,
R: KProcBlk)

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

effect FreeSlot(Slot)

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2.15 Allocation Functions

System Development Corporation
TM-6062/101/00

```
constant InsertSwap(L: list of SwapBlok,  
    AFTER: SwapBlok,  
    NEW: SwapBlok) ==  
(L..1 = AFTER => L :. NEW  
    <> InsertSwap(L :.2, AFTER, NEW);. L..1)
```


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2.15 Allocation Functions

System Development Corporation
TM-6062/101/00

transform ChainPageIO(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)

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2.15 Allocation Functions

System Development Corporation
TM-5062/101/00

transform ReleasePage(Page: VirtualPageName,
R: KProcBlok)

refcond R<:ProcessList & CheckASpace(R, Page.VMname, Page.A)
& 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)))

21 May 1978
2.15 Allocation Functions

System Development Corporation
TM-6062/101/00

transform SetSlot(PF: PageFrame,
Slot: PageSlot)

refcond PF.Status<:S"(ReadWrite, ReadOnly) & PF.Intransit ~ IN
& PF.ILOCK = 0 & PF.OLCK = 0 & ~PF.ULOCK
& PS.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

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2.15 Allocation Functions

System Development Corporation
TM-6062/101/00

transform AssignSlot(PF: PageFrame,
Slot: PageSlot,
R: KProcBlok)

refcond R:ProcessList & R.ProcName = SCHEDULER

effect SetSlot(PF, Slot)

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2.15 Allocation Functions

System Development Corporation
TM-6862/101/00

transform StealPageFrame(PF: PageFrame,
ID: RequestName,
Notify,
R: KProcBlok)

refcond R<:ProcessList & R.ProcName = SCHEDULER
& PF.Status = ReadWrite & ~PF.ULOCK & ~PF.TLOCK
& PF.ILOCK = 0 & PF.OLOCK = 0
& PF.Intransit == IN

effect FreePageFrame(PF)
& (PF.VirtAddr.Change ->
E"PS: PageSlot(PS.Status = Free
& EnqueueSwap(PF, OUT, PS, Notify, ID)))

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2.15 Allocation Functions

System Development Corporation
TM-6062/101/00

transform GetPageFrame(ID: RequestName,
R: KProcBlok,
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.ILOCK = 0 & PF.OLock = 0)
 => StealPageFrame(PF, ID, R,
 U"P: KProcBlok (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"P: KProcBlok (P.ProcName = SCHEDULER
 & P<:ProcessList))))

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2.16 Spooling Functions

System Development Corporation
TM-6062/101/00

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

System Development Corporation
TM-6062/101/00

```
transform RequestSpoolIO(Direction: (IN,OUT),
                          Slot: SpoolSlotAddress,
                          ID: RequestName,
                          Page: VPage,
                          R: KProcBlok)

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.ILOCK = 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: SwapBlok (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

System Development Corporation
TM-6862/181/88

transform ReleaseSpoolCylinder(V: SpoolCylinderAddress,
R: KProcBlok)
recond RealCyl(R, V).Exists & R.Proctype = NKCP & R.ProcessList
effect ~N"RealSpoolCyl(R, V).Exists
& N"SpoolStatus(RealSpoolCyl(R, V).Addr) = Free

21 May 1978

2.17 Send/Receive Message Functions

System Development Corporation

TM-6062/101/00

2.17: Send/Receive Message Functions

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 MsgBlk = structure of
    (Sender = ProcessName,
    MessageId = MessageId,
    Contents = T"L: list of Byte (C"L <= PageSize*1024),
    MsgLength = T"I: integer (I >= 0 & I <= PageSize*1024) )
```

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2.17 Send/Receive Message Functions

System Development Corporation

TM-6062/101/00

```
transform ReceiveMessage(Buffer: Address370,  
                          R: KProcBlok,  
                          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 = U"PF: PageFrame (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)
```

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2.17 Send/Receive Message Functions

System Development Corporation

TM-6062/101/00

```
transform SendMessage(ID: MessageId,  
    MessageLength: ByteOffset,  
    Message: Address370,  
    D,  
    R: KProcBlok)
```

```
rafcond R<:ProcessList & D<:ProcessList  
    & (SendMessageAllowed(R.ProcName, D.ProcName) | R.Proctype = TRUSTED)  
    & CheckVPage(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  
    (B<:ClockCompQueue & B.Proc = D.ProcName  
    & B.Reason = MessageReq & B.Id = ID.Name)  
    => N"D = D & N"ClockCompQueue = ClockCompQueue & N"R = R  
    <> N"D.MessagePending  
    & E1"M:MsgBlok (N"D.MessageQueue = D.MessageQueue || S"(M)  
    & M.Sender = R.ProcName  
    & M.Length = MessageLength & M.MessageId = ID  
    & A"i:ByteOffset (i < MessageLength ->  
    M.Contents.i = PF.Contents.(Message.2+i) ) )  
    & M.MessageId.Name = ( ID.MsgType = OneWay => 0  
    <> ID.Name)  
    & N"D.MessageQueue = D.MessageQueue ;. M)  
    & (ID.MsgType = OneWay => N"ClockCompQueue = ClockCompQueue  
    <> ID.MsgType = TwoWay => E"B:ClockBlok  
    (N"ClockCompQueue = ClockCompQueue || S"(B)  
    & B.Proc = R.ProcName  
    & B.Reason = MessageReq & B.ID = ID.Name  
    & B.Time = SYSTEM-TODClock + ID.Time)  
    <> ID.MsgType = Reply => E"B:ClockBlok  
    (B<:ClockCompQueue & B.Proc = R.ProcName  
    & B.Reason = MessageReq & B.ID = ID.Name  
    & N"ClockCompQueue =  
    ClockCompQueue ~ S"(B) ) )
```

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2.17 Send/Receive Message Functions

System Development Corporation

TM-6062/101/00

transform ReadCPUId(ID: ProcessorId,
R: KProcBlok)

effect N"ID = SYSTEM-CPUId

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2.18 Timing Functions

System Development Corporation
TM-6062/101/00

2.18: Timing Functions

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 SETTime: 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

21 May 1978
2.18 Timing Functions

System Development Corporation
TM-6062/101/00

transform SetClockComparator(TIME: UnsignedDoubleword,
R: KProcBlok)

effect E"B: ClockBlok (B<:N"ClockCompQueue & B.Proc = Requester
& B.Time = TIME & B.Reason = ClockReq
& A"z: ClockBlok (z<:N"ClockCompQueue
& z.Proc = B.Proc & z.Reason = ClockReq
-> z = B))
& N"R.ClockCompInterruptPending = False
& E1"x<:N"ClockCompQueue (N"SYSTEMClockComparator = x.Time
& N"SystemClockCompId = x)
& A"y<:N"ClockCompQueue (y.Time >= N"SYSTEMClockComparator)

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2.18 Timing Functions

System Development Corporation
TM-6862/101/00

```
transform ClockComparatorInterrupt()
refcond SystemClockCompId<:ClockCompQueue
  & E1"P: KProcBlok (P<:ProcessList & P.Name = SystemClockCompId.Proc)
  & LET"B = U"ClockBlok (SystemClockCompId = B)

/* Note: ClockComparatorInterrupt occurs when
   SYSTEM-ClockComparator < SYSTEM-TODClock */

effect B.Reason = ClockReq => N"P.ClockCompInterruptPending
  & 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:ClockBlok (x<:ClockCompQueue ->
  x.Time >= SYSTEMClockComparator)
  A"y,z:ClockBlok (y<:ClockCompQueue
    & z<:ClockCompQueue
    & z.Proc = y.Proc
    & z.Reason = ClockReq
    & y.Reason = ClockReq
    -> z = y)
ClockCompQueue ~= nil -> SystemClockCompId<:ClockCompQueue
  & SystemClockCompId.Time = SYSTEMClockComparator
```


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2.18 Timing Functions

System Development Corporation
TM-6062/101/00

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 * 4096)
 & N"R.CPUTimerInterruptPending = False
 & (R.TrackingQuantum => N"R.RemainingQuantum = SYSTEM-CPUTimer
 <>~R.TrackingQuantum => N"R.RemainingQuantum =
 R.RemainingQuantum-R.CPUTimer

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2.18 Timing Functions

System Development Corporation
TM-6062/101/00

transform ReadCPUTimer(R: KProcBlok,
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)

21 May 1978
2.18 Timing Functions

System Development Corporation
TM-6062/101/00

transform CPUTimerInterrupt()

refcond R.Proctype = NKCP

/* CPU timer interrupt occurs when R.Proctype = NKCP
& SYSTEM-CPUTimer < 0 */

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

System Development Corporation
TM-6062/101/00

transform SetIntervalTimer (Time: Integer,
R: KProcBlok)

refcond R.Proctype = NKCP

effect
N"SYSTEM-TIMER <= Time
& N"SYSTEM-TIMER >= Time - (Delta * 3 / 40)

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2.18 Timing Functions

System Development Corporation
TM-6062/101/80

transform ReadIntervalTimer(R: KProcBlok,
Time: integer /* output */)

refcond R.Proctype = NKCP

effect N"Time <= SYSTEM-TIMER
& N"Time <= SYSTEM-TIMER + (Delta * 3 / 40)

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2.18 Timing Functions

System Development Corporation
TM-6062/101/00

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

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2.19 IO Functions

System Development Corporation
TM-6062/101/00

2.19: IO Functions

This section contains the kernel functions that perform real IO. Details of the functions' operation may be found in the preliminary design document of KVM/370, TM-5855/200/00.

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

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

```
type LockedBox, PreprocessedChannelProgram, SeekArg, IDAW,
  CCWCount = T"1: integer (0 <= I & I < 65536)
```

```
variable IORequestCount: integer, LockedBoxList: set of LockedBox
constant LookCCW(PreprocessedChannelProgram, CCWCount): ChannelCommandWord,
  CheckTIC(PreprocessedChannelProgram, CCWCount, ByteOffset): boolean,
  LookIDA(PreprocessedChannelProgram, Address370, VPage): IDAW,
  IDACount(PreprocessedChannelProgram, CCWCount): VPage,
  LookSeek(PreprocessedChannelProgram, Address370): SeekArg
variable IOFLAGS(DeviceAddress, CCWOpCode): CCWAccessFlags
```

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2.19 IO Functions

System Development Corporation
TM-6062/101/00

```

transform RequestIO(Device: DeviceAddress /* 0..4095 */ ,
  ChannelProgram: PreprocessedChannelProgram
  /* includes CCWs, IDAW list,
  search and seek arguments */
  VM: 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(CCW) = nil
    & ~LookCCW(ChannelProgram,i-1).DataChain
    & CCW.Count = 1
    & CheckTIC(ChannelProgram,CCW.Addr,i))
  & (F.DataTransfer =>
    A"ii: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.OLOCK = 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.IDAWords(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.SLI))
          & (G.Class = DASD =>
            (F.Seek ->
              (G.FullDisk => True

```


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2.19 IO Functions

System Development Corporation
TM-6062/101/00

```
<>G.Horizontal => CCW.SeekAddr.Head<:G.Tracks
<>G.Vertical => CCW.SeekAddress.Cyl<:G.Cyls))
&(i=1 -> (CCW.Opcode = Seek | CCW.Opcode = SeekCylinder))
&(i=2 -> (CCW.Opcode = 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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2.19 IO Functions

System Development Corporation
TM-6062/101/00

effect N"IORequestCount = IORequestCount + 1

```
& E"LB: LockedBox (N"LockedBoxList = LockedBoxList || S" (LB)
  & LB.Num = IORequestCount
  & LB.ID = ID
  & LB.NCCWs = ChannelProgram.NCCWs
  & LB.Dev = Device & LB.Notify = R.ProcName
  & A"LBX<:LockedBoxList (LBX.Num < LB.Num)
  & A"i:integer (i > 0 & i <= ChannelProgram.NCCWs
    -> LET"CCWA = LookCCW(ChannelProgram,i)
    & LET"CCWN = (LB.ChanProg,i)

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

    & CCWN.Opcode = CCWA.Opcode & Modif(CCWN) = Modif (CCWA.)
    & CCWN.Count = CCWA.Count
    & CCWN.Addr = CCWA.Addr + LOC (LB)

    & (F.DataTransfer => A"j:integer (j > 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 = U"PF:PageFrame(PF<:RealPages
        & PF.Addr = AdN.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.ChanProg,CCWN.Addr)

      <>~F.Access & ~F.Seek => True)))
```

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2.19 IO Functions

System Development Corporation
TM-6062/101/00

transform StartIO(LockedBoxId: integer,
R: KProcBlok)

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:KProcBlok (B.ProcName = L.Notify)
& N"P.IOInterruptPending
& E"B:IOintBlok (B<:N"P.IOinterrupts & B.ID = L.ID & B.Dev = L.Dev)
& A"C: LBCCW (C<:L.ChanProg
-> LET"F = IOFlags(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 */

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2.19 IO Functions

System Development Corporation
TM-6062/101/00

transform CancelIO(ID: RequestName,
R: KProcBlok)

refcond 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"W: Address370
(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)))

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2.19 10 Functions

System Development Corporation
TM-6062/101/00

transform WaitIO (Device: DeviceAddress,
ChannelProgram: PreprocessedChannelProgram,
R: KProcBlok)

```
refcond R<:ProcessList
& R.ProcType = NKCP
& LET"G = GrantedAccess (Device, R.ProcName)
& A"C:ChannelControlWord (C<:ChannelProgram.CCWs ->
  LET"F = IOFlags (Device, C.OpCode)
  & ~F.TIC
  & A"W: IDAW (W<:C.IDAList
    -> 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.ILOCK = 0
      & A"j:integer (j > 0
        & j < ChannelProgram.NCCWs
    -> LET"C2 = LookCCW (ChannelProgram, j)
    & (C2.SKIP | IOFlags (Device, C2.OpCode).Access ~= Read
      | A"W2:IDAW
    (W2<:C2.IDAList -> RealAddress (R.AddressSpace, W2.1).1 ~= RA.1)))
    <> F.Access = Read => C.SKIP |
      PF.OLOCK = 0
      & A"K:integer
    (K > 0 & K < ChannelProgram.NCCWs
    -> LET"C3 = LookCCW (ChannelProgram, K)
    & (IOFlags (Device, C3.OpCode).Access ~= Read
      | A"W3:IDAW (W3<:C3.IDAWords ->
        RealAddress (R.AddressSpace, W3.1).1 ~= RA.1)))
    <> true)
    & (F.DASD -> G.FullDisk)))
```

effect MachineDependent

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3.1.1 Operator Process (Informal)

System Development Corporation

TM-6062/101/00

3.1.1: Operator Process Informal Description

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.

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3.1.1 Operator Process (Informal)

System Development Corporation

TM-6062/101/00

KVM/370 Operator Commands
(see notes at end of table)

Command	S M	Resp Exp	Map	Destin- ation(s)	Category
AUTOLOG	S	Y	N	AuthProcess	1,1
DIAL	not legal				0,0
FORCE+USERID	S	N(1)	U->N	NKCP	*3,0
FORCE+ALL	M	N(1)	N	all NKCPs	*2,0
INDICATE+LOAD	M	Y	N	all NKCPs	2,3
INDICATE+QUEUES	M	Y	N	all NKCPs	2,4
INDICATE+IO	S	Y	N	I/O Scheduler	1,1
INDICATE+PAGING	S	Y	N	I/O Paging Scheduler	1,1
INDICATE+USER	S	Y	U->N	NKCP	3,1
LOGON	not legal				0,0
LOGOFF	not legal				
HALT	S	(2)	N	Kernel	5,0
LOCK+USERID	S	Y	U->N	NKCP	3,1
LOCK+SYSTEM	S	Y	N	NKCP	1,1
MESSAGE+USERID	S	N	U->N	NKCP	*3,0
MESSAGE+ALL	M	N	N	all NKCPs	*2,0
MONITOR+NKCP	S	Y	N	NKCP	1,1
MONITOR+ALL	M	Y	N	all NKCPs	2,2
NETWORK	S	Y	N	Network Process	1,1
QUERY+PAGING	S	Y	N	I/O Paging Scheduler	1,1
QUERY+PRIORITY	S	Y	U->N	NKCP	3,1
QUERY+SASSIST+NKCP	S	Y	N	NKCP	1,1
QUERY+SASSIST+ALL	M	Y	N	all NKCPs	2,2
QUERY+DASD	S	Y	N	AuthProcess	1,1
QUERY+TAPES	S	Y	N	URProcess	1,1
QUERY+LINES	S	Y	N	AuthProcess	1,1
QUERY+GRAF	S	Y	N	AuthProcess	1,1
QUERY+SYSTEM	S	Y	N	AuthProcess	1,1
QUERY+NAMES	S	Y	N	AuthProcess	1,1
QUERY+USERS	S	Y	N	AuthProcess	1,1
QUERY+USERID	S	Y	N	AuthProcess	1,1
QUERY+UR	S	Y	N	URProcess	1,1
QUERY+ALL	M	Y	N	AuthProcess, URProcess, Kernel	9,2

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3.1.1 Operator Process (Informal)

System Development Corporation
TM-6062/101/00

Command	S M	Resp Exp	Map	Destin- ation(s)	Category
QUERY+DUMP	S	Y	N	Dump	1.1
QUERY+TOSK	M	Y	N	Processor	2.2
QUERY+STORAGE	S	(2)	N	all NKCPs	5.0
QUERY+RADNR	S	Y	R->T	URProcess or AuthProcess	4.1
QUERY+FILES	S	Y	N	URProcess	1.1
QUERY+READER	S	Y	N	URProcess	1.1
QUERY+PRINTER	S	Y	N	URProcess	1.1
QUERY+PUNCH	S	Y	N	URProcess	1.1
QUERY+HOLD	S	Y	N	URProcess	1.1
QUERY+LOGMSG				processed directly	8.0
SET+FAVORED	S	Y	U->N	NKCP	3.1
SET+RESERVED	S	Y	U->N	NKCP	3.1
SET+PRIORITY	S	Y	U->N	NKCP	3.1
SET+SASSIST+NKCP	S	Y	N	NKCP	1.1
SET+SASSIST+ALL	M	Y	N	all NKCPs	2.2
SET+LOGMSG				processed directly	8.0
SET+DUMP	S	N	N	Dump	*1.0
SET+RECORD		not legal		Processor	0.0
SET+MODE		not legal			0.0
SHUTDOWN	M	N	N	AuthProcess, URProcess, all NKCPs	10.0
SLEEP		not legal			0.0
UNLOCK+USERID	S	Y	U->N	NKCP	3.1
UNLOCK+SYSTEM	S	Y	N	NKCP	1.1
UNLOCK+VIRT		not legal			0.0
WARNING+USERID	S	N	U->N	NKCP	*3.0
WARNING+ALL	M	N	N	NKCP	*2.0
BACKSPAC	S	Y	N	URProcess	1.1
CHANGE	S	Y	N	URProcess	1.1
DRAIN	S	Y	N	URProcess	1.1
FLUSH	S	Y	N	URProcess	1.1
FREE	S	Y	N	URProcess	1.1
HOLD	S	Y	N	URProcess	1.1
ORDER	S	Y	N	URProcess	1.1
PURGE	S	Y	N	URProcess	1.1
REPEAT	S	Y	N	URProcess	1.1
SPACE	S	Y	N	URProcess	1.1
START	S	Y	N	URProcess	1.1
TRANSFER	S	Y	N	URProcess	1.1

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Command	S M	Resp Exp	Map	Destin- ation(s)	Category
ATTACH+CHANNEL	not	legal			0,0
ATTACH+RADDR	S	Y	R->T	URProcess or AuthProcess	4,1
DETACH+CHANNEL	not	legal			0,0
DETACH+RADDR	S	Y	R->T	URProcess or AuthProcess	4,1
DISABLE	S	Y	N	Network Process	1,1
DISCONN	not	legal			0,0
ENABLE	S	Y	N	Network Process	1,1
LOADBUF	S	Y	N	URProcess	1,1
VARY	S	Y	R->T	URProcess or AuthProcess	4,1
ACNT+USERIDS	Both	Y	U->N	some NKCPs	7,2
ACNT+ALL	M	Y	N	all NKCPs	2,2
DCP	S	Y	N	NKCP	1,1
DMCP	S	Y	N	NKCP	1,1
LOCATE+USERID	S	/	U->N	NKCP	3,1
LOCATE+RADDR	S	Y	R->T	URProcess or AuthProcess	4,1
SAVESYS	not	legal			0,0
STCP	S	Y	N	NKCP	1,1

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Notes:

The column headings are as follows:

Command = command name

S/M = single message versus multiple messages sent

Resp 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.

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3.1.1 Operator Process (Informal)

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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

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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

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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 each 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

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DASD, LINES, GRAF,
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

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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

LOGMSG - 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, URProcess, 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

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3.1.1 Operator Process (Informal)

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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

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3.1.1 Operator Process (Informal)

System Development Corporation

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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)

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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

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3.1.1 Operator Process (Informal)

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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 VM/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

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3.1.1 Operator Process (Informal)

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OPERATOR COMMANDS:
PROGRAM ANALYSIS
AND
MONITOR
FUNCTIONS

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

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3.1.1 Operator Process (Informal)

System Development Corporation
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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/370

STCP (C)

"Change the contents of real processor storage."

[extend syntax to provide NKCP id (security level)]

reflect message to NKCP
print NKCP response

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3.1.1 Operator Process (Informal)

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Authorization Process
- Responses -

UserIdMapped

ResponseToOpRequest

NKCP Requests

OperatorMessage

QueryLogMsg

ResponseToOpRequest

Other Processes
- Responses -

ResponseToOpRequest

Other Processes
- Requests -

OperatorMessage

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3.1.2 Operator Process (Formal)

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3.1.2: Operator Process Formal Specification

module OpProcess

type

DeviceTypes,

Char,

String = list of Char.

MessageLabel = (ResponseToOpRequest, OperatorRequest, MappedUserId,
AddrNkcp, DeleteNkcp, OpMsgPrinted, OpHitAttn, OpRequestRead),

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

ProcessName,

MessageId,

CommandName = (DIAL, LOGON, SET+RECORD, SET+MODE, SLEEP,
UNLOCK+SYSTEM, UNLOCK+VIRT, ATTACH+CHANNEL, DETACH+CHANNEL,
DISCONN, SAVESYS,
AUTOLOG, INDICATE+IO, INDICATE+PAGING,
LOGOFF, LOCK+SYSTEM, MONITOR+NKCP, NETWORK, QUERY+PAGING,
QUERY+SASSIST+NKCP, QUERY+DASD, QUERY+TAPES, QUERY+LINES,
QUERY+GRAF, QUERY+SYSTEM, QUERY+NAMES, QUERY+USERS, QUERY+USERID,
QUERY+UR, QUERY+DUMP, QUERY+FILES, QUERY+READER, QUERY+PRINTER,
QUERY+PUNCH, QUERY+HOLD, SET+SASSIST+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+SASSIST+ALL, QUERY+TOSK, SET+SASSIST+ALL,
WARNING+ALL, ACNT+ALL,
FORCE+USERID, INDICATE+USER, LOCK+USERID, MESSAGE+USERID,
QUERY+PRIORITY, SET+FAVORED, SET+RESERVED, SET+PRIORITY,
UNLOCK+USERID, WARNING+USERID, LOCATE+USERID,
QUERY+RADOR, ATTACH+RADOR, DETACH+RADOR, VARY, LOCATE+RADOR,
HALT, QUERY+STORAGE,
ACNT+USERIDS, QUERY+LOGMSG, SET+LOGMSG, QUERY+ALL, SHUTDOWN),

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

Cat1 = T" (AUTOLOG, INDICATE+IO, INDICATE+PAGING,
LOGOFF, LOCK+SYSTEM, MONITOR+NKCP, NETWORK, QUERY+PAGING,
QUERY+SASSIST+NKCP, QUERY+DASD, QUERY+TAPES, QUERY+LINES,
QUERY+GRAF, QUERY+SYSTEM, QUERY+NAMES, QUERY+USERS, QUERY+USERID,
QUERY+UR, QUERY+DUMP, QUERY+FILES, QUERY+READER, QUERY+PRINTER,
QUERY+PUNCH, QUERY+HOLD, SET+SASSIST+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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3.1.2 Operator Process (Formal)

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Cat2 = T" (FORCE-ALL, INDICATE-LOAD, INDICATE-QUEUES, MESSAGE-ALL,
MONITOR-ALL, QUERY-SASSIST-ALL, QUERY-TASK, SET-SASSIST-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 = (OpRequest, 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)

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3.1.2 Operator Process (Formal)

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variable

Answer: list of Answer.

PendingRequests: set of PendingRequest.

LogMessage: set of LogLine.

CommandExpected: boolean.

ConsoleOutputState: ConsoleOutputStatus.

CurrentNkcp: set of ProcessName

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3.1.2 Operator Process (Formal)

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```
initial
Answers = nil
&
PendingRequests = Empty
&
LogMessage = Empty
&
CommandExpected = true
&
ConsoleOutputState = Idle
&
CurrentNkops = 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))
```

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3.1.2 Operator Process (Formal)

System Development Corporation
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```
constant
OpProcess, URProcess, AuthProcess, AcntProcess, UpdaterProcess:
    ProcessName,
IOPagingScheduler, IOScheduler, NetworkProcess, DumpProcessor:
    ProcessName,
TrustedProcesses = S" (OpProcess, URProcess, AuthProcess,
    AcntProcess, UpdaterProcess),
MsgName (String): MessageLabel,
Destination (CommandName): ProcessName,
DeviceType (DeviceAddress): DeviceTypes,
Raddr (String): DeviceAddress,
ClockRead: String,
ErrorMsg: String,
NewMsgId: MessageId,
SendMessage (ProcessName): KernelFunction,
KFcn (CommandName): KernelFunction,
DefinedElsewhere: boolean = true,
MakeString (set of LogLine): String,
LogPrompt: String,
Line// (String): T"l: integer (1 <= l & l <= 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)
```

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3.1.2 Operator Process (Formal)

System Development Corporation

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transform OpCat0(Command: CommandName)

refcond Command<:Cat0

effect N"Answers = Answers;. (ClockRead, ErrorMsg)
&
N"CommandExpected

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3.1.2 Operator Process (Formal).

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transform OpCat1 (Command: CommandName)

re?cond CommandExpected
&
Command<:Cat1

effect N"PendingRequests =
 (Command = SET-DUMP =>
 PendingRequests
 <> PendingRequests || S"((NewMsgId,
 OpRequest,
 Command,
 S"((Destination(Command),
 nil,
 NoResponse))))))
&
N"CommandExpected
&
KernelCalled (SendMessage (Destination (Command)))

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3.1.2 Operator Process (Formal)

System Development Corporation
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```
transform OpCat2(Command: CommandName)

refcond CommandExpected
&
Command<:Cat2

effect N"CommandExpected
&
A"P:ProcessName(P<:CurrentNkcp ->
      KernelCalled(SendMessage(P)))
&
(Command ~<:S"(FORCE+ALL,WARNING+ALL) =>
  N"PendingRequests = PendingRequests ||
  S"((NewMsgId,
      OpRequest,
      Command,
      S"R:ResponseSlot(E"P:ProcessName
        (P<:CurrentNkcp
          &
          R = (P,nil,NoResponse))))))
  <> N"PendingRequests = PendingRequests)
```

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3.1.2 Operator Process (Formal)

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transform OpCat3(Command: CommandName,
Nkcps: set of ProcessName)

refcond Command<:Cat3

```
effect (Nkcps<=CurrentNkcps =>
  N"PendingRequests =
    (Command<:S" (FORCE=USERID,
      MESSAGE=USERID,
      WARNING=USERID) => PendingRequests
    <> PendingRequests ||
    S"((NewMsgId,
      OpRequest,
      Command,
      S"R: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)
```

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3.1.2 Operator Process (Formal)

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```
transform OpCat4(Command: CommandName,  
                 Raddr: DeviceAddress)  
  
refcond CommandExpected  
&  
Command<:Cat4  
  
effect N"PendingRequests = PendingRequests ||  
      S"((NewMsgId,  
          OpRequest,  
          Command,  
          S"((DeviceType(Raddr) = UnitRecord =>  
              URProcess  
              <> AuthProcess),  
              nil,  
              NoResponse))))  
&  
N"CommandExpected  
&  
(DeviceType(Raddr) = UnitRecord =>  
    KernelCalled(SendMessage(URProcess))  
    <> KernelCalled(SendMessage(AuthProcess)))
```


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3.1.2 Operator Process (Formal)

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transform OpCat5(Command: CommandName)

refcond CommandExpected
&
Command<:Cat5

effect KernelCalled(KFcn(Command))
&
N"Answers = Answers;. (ClockRead, KernelResult)
&
N"CommandExpected

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3.1.2 Operator Process (Formal)

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TM-6062/101/00

transform OpCat6(Command: CommandName)

refcond CommandExpected

&

Command<:Cat3 || S" (ACNT-USERIDS)

effect N"PendingRequests = PendingRequests ||

S" ((NewTagId,

MapUserId,

Command,

S" ((AuthProcess,nil,NoResponse)))

&

N"CommandExpected

&

KernelCalled (SendMessage (AuthProcess))

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3.1.2 Operator Process (Formal)

System Development Corporation
TM-6062/101/00

transform OpCat7(Command: CommandName,
Nkcp: set of ProcessName)

refcond Command = ACNT-USERIDS

effect (Nkcp<<=CurrentNkcp ->
N"PendingRequests = PendingRequests ||
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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transform OpCat8a(Command: CommandName)

refcond CommandExpected
&
Command = QUERY-LOGMSG

effect N"Answers = Answers;. (ClockRead, MakeString(LogMessage))
&
N"CommandExpected

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3.1.2 Operator Process (Formal)

System Development Corporation
TM-6062/101/00)

transform OpCat8b(Command: CommandName)

refcond CommandExpected
&
Command = SET-LOGMSG

effect N"Answers = Answers;.(ClockRead,LogPrompt)
&
N"CommandExpected = false

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3.1.2 Operator Process (Formal)

System Development Corporation
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transform OpCat8c(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)

System Development Corporation
TM-6062/101/00

```
transform OpCat9(Command: CommandName)
refcond CommandExpected
&
  Command = QUERY+ALL
effect N"CommandExpected
&
  N"PendingRequests = PendingRequests ||
  S"((NewMsgId,
    Command,
    S"((Kernel, KernelResult, Responded),
      (AuthProcess, nil, NoResponse),
      (URProcess, nil, NoResponse))))
&
  KernelCalled(KFcn(QUERY+STORAGE))
&
  KernelCalled(SendMessage(AuthProcess))
&
  KernelCalled(SendMessage(URProcess))
```

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3.1.2 Operator Process (Formal)

System Development Corporation
TM-6062/101/00

```
transform OpCat10(Command: CommandName)
refcond CommandExpected
&
Command = SHUTDOWN
effect N"CommandExpected
&
KernelCalled(KFcn(SHUTDOWN))
&
KernelCalled(SendMessage(AuthProcess))
&
KernelCalled(SendMessage(URProcess))
&
KernelCalled(SendMessage(AcntProcess))
&
A"P:ProcessName(P<:CurrentNkcp ->
    KernelCalled(SendMessage(P)))
```


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3.1.2 Operator Process (Formal)

System Development Corporation
TM-6062/101/00

transform AUTH1 (Nkcp: ProcessName)

```
effect (Nkcp<:CurrentNkcp =>  
      Error  
      &  
      N"CurrentNkcp = CurrentNkcp  
      <> NoError  
      &  
      N"CurrentNkcp = CurrentNkcp || S" (Nkcp))
```

21 May 1978
3.1.2 Operator Process (Formal)

System Development Corporation
TM-6062/101/00

transform AUTH2(Nkcp: ProcessName)

```
effect (Nkcp<:CurrentNkcp =>  
      NoError  
      &  
      N"CurrentNkcp = CurrentNkcp ~ S" (Nkcp)  
      <>  
      Error  
      &  
      N"CurrentNkcp = CurrentNkcp)
```

21 May 1978
3.1.2 Operator Process (Formal)

System Development Corporation
TM-6062/101/00

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(R1<:P.Responses &
R1 ~ R

&
R1.State = NoResponse) =>
N"Answers = Answers

&
N"PendingRequests = PendingRequests ~ S"(P) ||
S"((P.MsgId,
P.Kind,
P.Command,
P.Responses ~ S"(R) ||
S"((R.Respondent,
Response(Text),
Responded)))

<> N"PendingRequests = PendingRequests ~ S"(P)
&
N"Answers = Answers;.OpResponse(P))

<> Error)

21 May 1978
3.1.2 Operator Process (Formal)

System Development Corporation
TM-6062/101/00

```
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 =>
    OpCat6(Command)
  <> Command<:Cat4 =>
    OpCat4(Command, Raddr(Text))
  <> Command<:Cat5 =>
    OpCat5(Command)
  <> Command = ACNT-USERIDS =>
    OpCat6(Command)
  <> Command = QUERY-LOGMSG =>
    OpCat8a(Command)
  <> Command = SET-LOGMSG =>
    OpCat8b(Command)
  <> Command = QUERY-ALL =>
    OpCat9(Command)
  <> Command = SHUTDOWN =>
    OpCat10(Command)
  <> Error))
<> OpCat8c(Line#(Text), Line(Text))
```

21 May 1978

3.1.2 Operator Process (Formal)

System Development Corporation
TM-6062/101/00

```
transform MsgNkcp(MsgId: MsgId,
                  Text: String,
                  Source: ProcessName)

refcond Source ~<:TrustedProcesses ||
    S" (IOPagingScheduler, IOScheduler,
        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))
```

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3.1.2 Operator Process (Formal)

System Development Corporation
TM-6062/101/00

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))

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3.1.2 Operator Process (Formal)

System Development Corporation
TM-6062/101/00

transform MsgIOPS(MsgId: MessageId,
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"Answers = Answers;. (ClockRead, Text)
<> Error))

21 May 1978
3.1.2 Operator Process (Formal)

System Development Corporation
TM-6062/101/00

transform MsgIOS(MsgId: MessageId,
Text: String,
Source: ProcessName)

refcond Source = IOScheduler

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))

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3.1.2 Operator Process (Formal)

System Development Corporation
TM-6062/101/00

```
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))
```

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3.1.2 Operator Process (Formal)

System Development Corporation

TM-6062/101/00

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 =>
N"Answers = Answers;.(ClockRead,Text)
<> Error))

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3.1.2 Operator Process (Formal)

System Development Corporation
TM-6062/101/00

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,Nkcp(Text))
<> P.Command = ACNT+USERIDS =>
OpCat7(P.Command,Nkcp(Text))
<> Error)
<> Error)
<> Error))
<> (MsgName(Text) = OperatorRequest =>
N"Answers = Answers:.(ClockRead,Text)
<> MsgName(Text) = AddNkcp =>
AUTH1(Nkcp(Text))
<> MsgName(Text) = DeleteNkcp =>
AUTH2(Nkcp(Text))
<> Error))

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3.1.2 Operator Process (Formal)

System Development Corporation
TM-6862/101/00

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 = OpRequest =>
      (MsgName(Text) = ResponseToOpRequest =>
      ProcessedResponse(P.Text, Source)
      <> Error)
      <> P.Kind = PrintOpMsg =>
      (MsgName(Text) = OpMsgPrinted =>
      (Answers = nil =>
      N"ConsoleOutputState = Idle
      <> KernelCalled(SendMessage(
      NetworkProcess))
      &
      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)

System Development Corporation
TM-6862/101/00

```
<> MsgName(Text) = OpHitAttn =>  
    N"CommandExpected  
    &  
    N"ConsoleOutputState = Idle  
    &  
    KernelCalled(SendMessage(NetworkProcess))  
    <> Error)  
    <> Error))  
<> (MsgName(Text) = OperatorRequest =>  
    N"Answers = Answers:.(ClockRead,Text)  
    <> MsgName(Text) = OpHitAttn =>  
        N"CommandExpected  
        &  
        N"ConsoleOutputState = Idle  
        &  
        KernelCalled(SendMessage(NetworkProcess))  
    <> Error))
```

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3.1.2 Operator Process (Formal)

System Development Corporation
TM-6062/101/00

```
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 = IOPagingScheduler =>  
           MsgIOPS(MsgId, Text, Source)  
         <> Source = IOScheduler =>  
           MsgIOS(MsgId, Text, Source)  
         <> Source = NetworkProcess =>  
           MsgNet(MsgId, Text, Source)  
         <> Source = DumpProcessor =>  
           MsgDump(MsgId, Text, Source)  
         <> Source ~<: TrustedProcesses ||  
           S" (IOPagingScheduler, IOScheduler,  
             NetworkProcess, DumpProcessor) =>  
             MsgNkcp(MsgId, Text, Source)  
         <> Error)  
         <> Error)  
         <> Error)  
         &  
         KernelCalled(ReceiveInterrupts)  
         &  
         KernelCalled(ReleaseCPU)  
       )  
end OpProcess
```

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3.2.1 Unit Record Process (Informal)

System Development Corporation

TM-6062/101/00

3.2.1: Unit Record Process Informal Description

This section contains the informal description of the Unit Record Process of KVM/370.

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.

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3.2.1 Unit Record Process (Informal)

System Development Corporation
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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.

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3.2.1 Unit Record Process (Informal)

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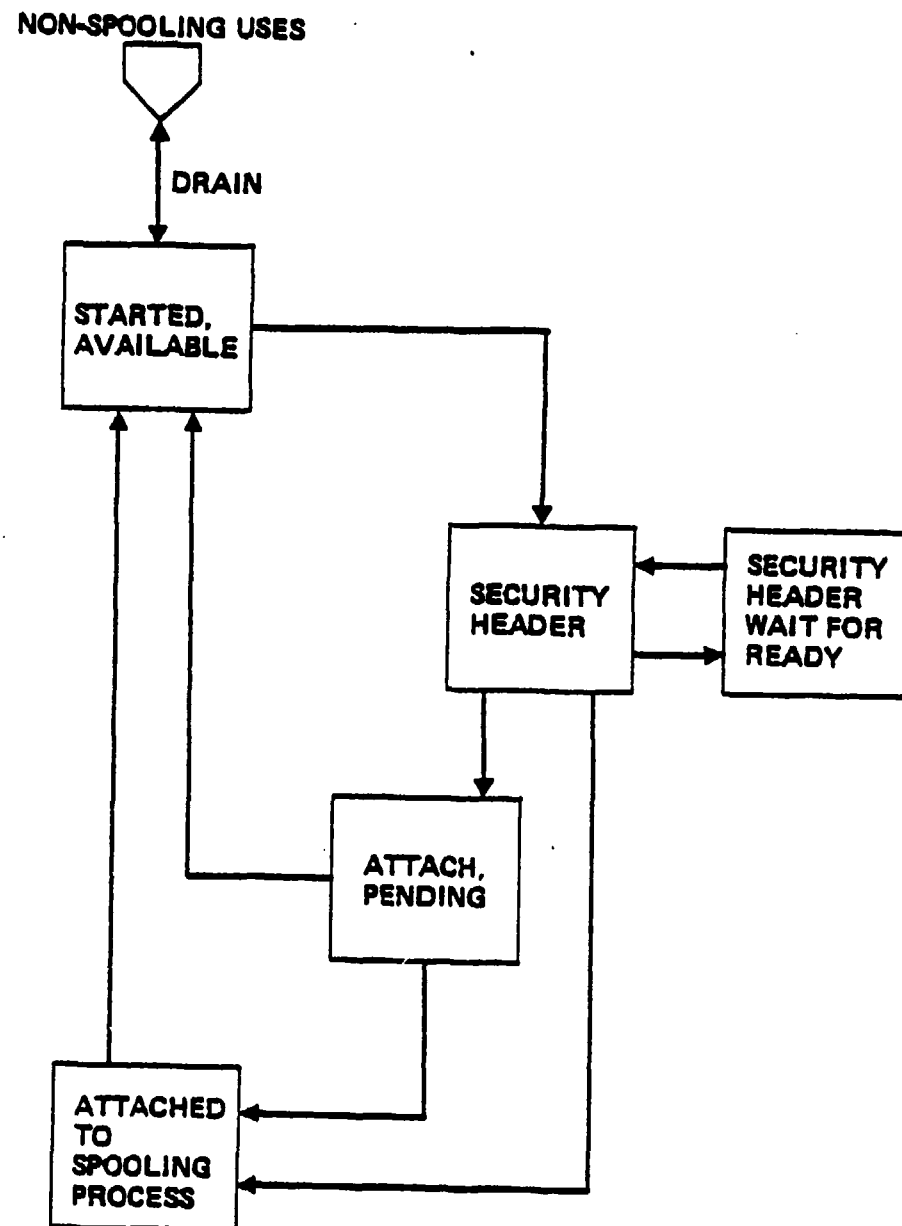


Figure 1

THE READER SPOOLING CYCLE

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3.2.1 Unit Record Process (Informal)

System Development Corporation

TM-6062/101/00

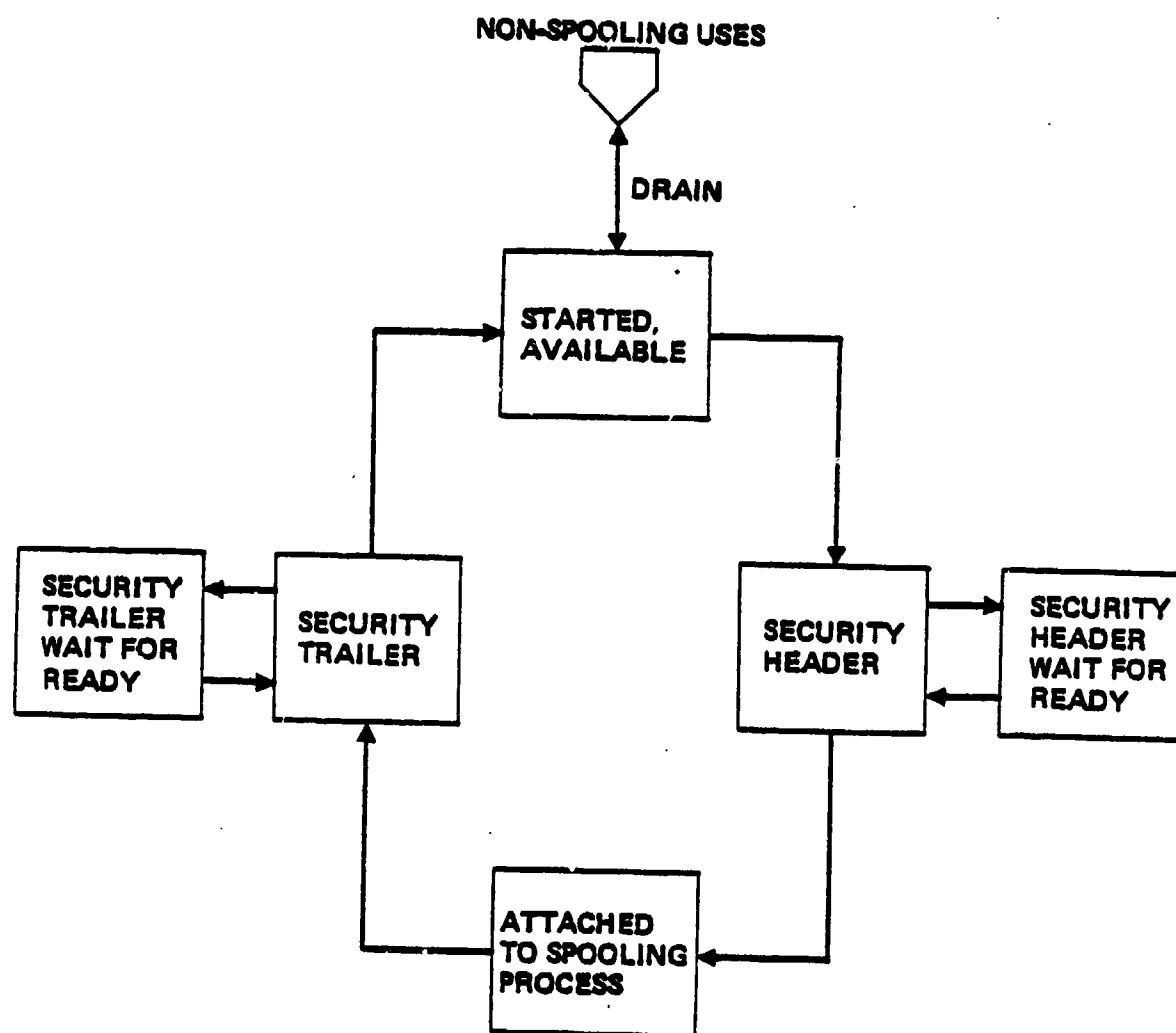


Figure 2

Printer and Punch
Spooling Cycles

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3.2.1 Unit Record Process (Informal)

System Development Corporation
TM-6062/101/00

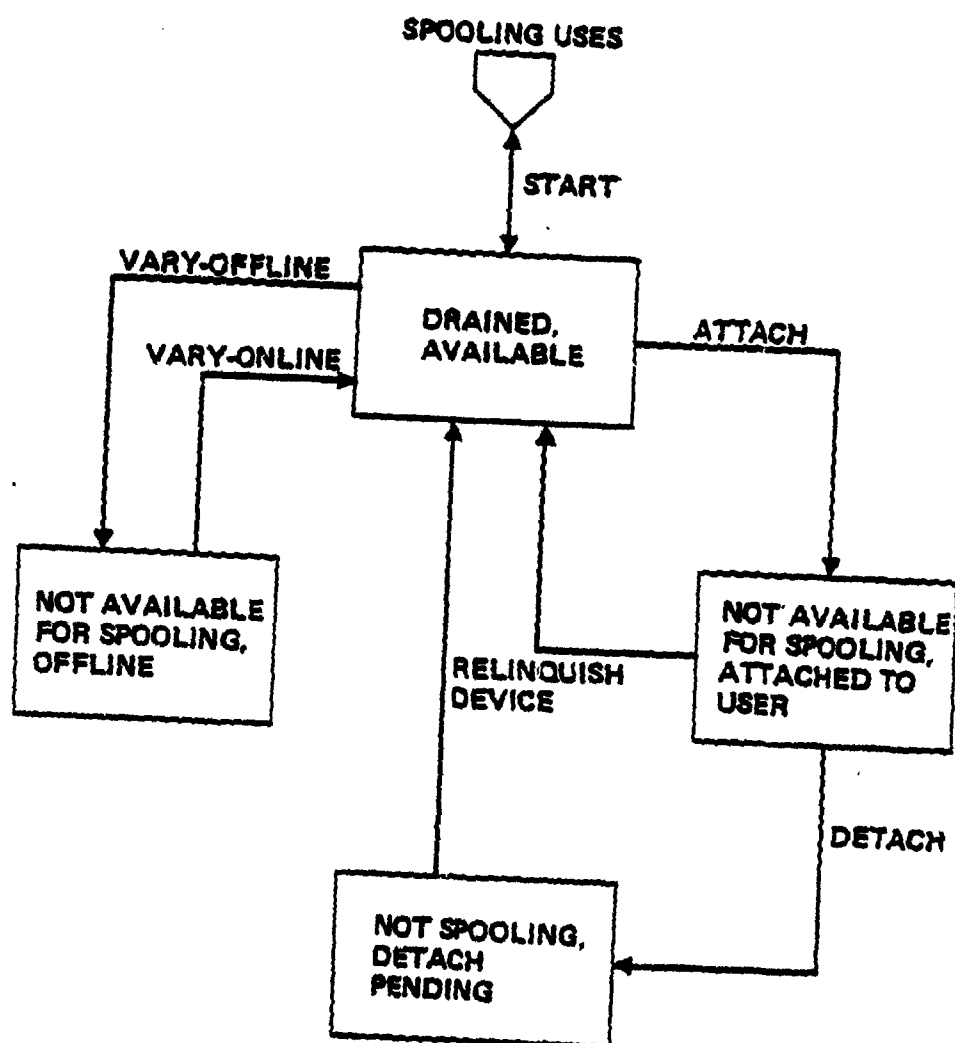


Figure 3
NON-SPOOLING CYCLES FOR ALL UNIT RECORD DEVICES

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3.2.1 Unit Record Process (Informal)

System Development Corporation
TM-6062/101/00Operator Commands
sent first to Unit Record Process

Command	S/M	Map	Cate- gory	Destination(s)
QUERY-UR	Both	-	0	Attached Processes
QUERY-ALL	Both	-	0	Attached Processes
QUERY-RADDR	Both	-	0	Attached Processes
QUERY-TAPES	Both	-	0	Attached Processes
QUERY-FILES-USERID	S	U->N	3	NKCP
QUERY-FILES-ALL	M	-	2	all NKCPs
QUERY-READER-USERID	S	U->N	3	NKCP
QUERY-READER-SPOOLID	S	-	1	NKCP
QUERY-READER-ALL	M	-	2	all NKCPs
QUERY-PRINTER-USERID	S	U->N	3	NKCP
QUERY-PRINTER-SPOOLID	S	-	1	NKCP
QUERY-PRINTER-ALL	M	-	2	all NKCPs
QUERY-PUNCH-USERID	S	U->N	3	NKCP
QUERY-PUNCH-SPOOLID	S	-	1	NKCP
QUERY-PUNCH-ALL	M	-	2	all NKCPs
QUERY-HOLD	M	-	2	all NKCPs
SHUTDOWN	See command description			
BACKSPAC	S	-	4	Attached Process
CHANGE-USERID	S	U->N	3	NKCP
CHANGE-SYSTEM-CLASS-ALL	M	-	2	all NKCPs
CHANGE-SYSTEM-SPOOLID	S	-	1	NKCP
DRAIN	See command description			
FLUSH	S	-	4	Attached Process
FREE	S	U->N	3	NKCP
HOLD	S	U->N	3	NKCP
ORDER-USERID	S	U->N	3	NKCP
ORDER-SYSTEM	Both	-	6	some NKCPs
PURGE-USERID	S	U->N	3	NKCP
PURGE-SYSTEM	Both	-	6	some NKCPs
REPEAT	S	-	4	Attached Process
SPACE	S	-	5	Attached Process
START	See command description			
TRANSFER	See command description			
ATTACH	See command description			
DETACH	See command description			
LOADBUF	See command description			
VARY	See command description			
LOCATE	S	-	7	Attached Process

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3.2.1 Unit Record Process (Informal)

System Development Corporation

TM-6062/101/00

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." If

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3.2.1 Unit Record Process (Informal)

System Development Corporation

TM-6062/101/00

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:

- o the reader is not cleared to read this deck (operator error); or
- o 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.

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3.2.1 Unit Record Process (Informal)

System Development Corporation

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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.

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3.2.1 Unit Record Process (Informal)

System Development Corporation
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OPERATOR PROCESS - Requests -

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

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3.2.1 Unit Record Process (Informal)

System Development Corporation
TM-6862/181/00

[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)

System Development Corporation

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gather responses
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

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3.2.1 Unit Record Process (Informal)

System Development Corporation

TM-6062/101/80

"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 ids
along with all user ids]

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3.2.1 Unit Record Process (Informal)

System Development Corporation

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```
user id, SYSTEM spoolid -  
  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 spoolid 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

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3.2.1 Unit Record Process (Informal)

System Development Corporation

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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 on (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

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3.2.1 Unit Record Process (Informal)

System Development Corporation

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Authorization Process
- Responses -

AddedNkcp

CannotAddNkcp

UserIdMapped

Authorization Process
- Requests -

AttachDevice

DeleteNkcp

NKCP Requests

AssignSpoolDevice

ReleaseSpoolDevice

DetachDevice

NKCP Responses

ResponseToOpRequest

DetachDevice

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/E3

3.2.2: Unit Record Process
Formal Specification

module URProcess

type

DeviceAddress,

Char,

String = list of Char,

HardwareStatus,

MessageId,

ProcessName,

Class,

ResponseStatus = (NoResponse, Responded),

RelDevRequestStatus = (NoNeed, ShouldSend, Sent),

CommandName = (QUERY-UR-ALL, QUERY-RADDR,
QUERY-FILES-USERID-, QUERY-FILES-ALL,
QUERY-ROPRPU-USERID, QUERY-ROPRPU-SPOOLID,
QUERY-ROPRPU-ALL, QUERY-HOLD, BACKSPAC, CHANGE-USERID,
CHANGE-SYSTEM, DRAIN, FLUSH, FREE, HOLD, ORDER-USERID,
ORDER-SYSTEM, PURGE-USERID, PURGE-SYSTEM, REPEAT, SPACE,
TRANSFER, LOCATE-RADDR),

RequestCategory = (OpRequest, MapUserId, NeedNkcp, RelinquishDevice),

InputDeviceStatus = (SecurityHeader, SecurityHeaderWaitForReady,
AttachPending, AttachedToSpoolingProcess, Available,
AttachedToUser, DetachPending, OffLine),

OutputDeviceStatus = (SecurityHeader, SecurityHeaderWaitForReady,
AttachedToSpoolingProcess, SecurityTrailer,
SecurityTrailerWaitForReady, Available, AttachedToUser,
DetachPending, OffLine),

TapeDriveStatus = (Available, AttachedToUser, OffLine, DetachPending),

ActivityStatus = (NotSpooling, Drained, Started, Draining),

Spoolid = structure of(
Process = ProcessName,
File = T"l:integer(0 <= I & I <= 999)),

ODRequestStatus = (Processing, WaitingForDevice),

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3.2.2 Unit Record Process (Formal)

System Development Corporation

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OutputDeviceRequest = structure of (
 Process = ProcessName,
 RequestedClasses = set of Class,
 AttachedDevice = DeviceAddress,
 State = ODRRequestStatus),

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)

System Development Corporation

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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-RADDR, 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" (BACKSPAC, 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,
OpProcess, URProcess, AuthProcess, AcntProcess, UpdaterProcess:
 ProcessName,
TrustedProcesses = S" (OpProcess, URProcess, AuthProcess,
 AcntProcess, UpdaterProcess)

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3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

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.
CurrentNkcps: set of NkcpEntry.
PendingRequests: set of PendingRequest

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

```
Initial
PendingRequests = Empty
&
CurrentNkps = Empty
&
PrinterSpoolRequests = Empty
&
~ShuttingDown
&
A"R:ReaderEntry(R<:Readers ->
  (R.State = Drained
  &
  R.CyclePosition = Available
  &
  R.AttachedProcess = URProcess
  &
  R.LineBuffer = nil
  &
  R.ClassesServedCurrently = Empty
  &
  R.ClassesServedNextCycle = Empty))
&
A"P:PrinterEntry(P<:Printers ->
  (P.State = Drained
  &
  P.CyclePosition = URProcess
  &
  P.AttachedProcess = URProcess
  &
  P.ClassesServedCurrently = Empty
  &
  P.ClassesServedNextCycle = Empty
  &
  P.RelinquishDeviceRequestState = NoNeed))
&
A"P:PunchEntry(P<:Punches ->
  (P.State = Drained
  &
  P.CyclePosition = URProcess
  &
  P.AttachedProcess = URProcess
  &
  P.ClassesServedCurrently = Empty
  &
  P.ClassesServedNextCycle = Empty
  &
  P.RelinquishDeviceRequestState = NoNeed))
&
A"T:TapeDriveEntry(T<:TapeDrives ->
  (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"Ti,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 ->
    (R.Raddr ~ Pr.Raddr & R.Raddr ~ Pu.Raddr & R.Raddr ~ T.Raddr
      &
      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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3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

```
((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"DR:OutputDeviceRequest((DR<:PrinterSpoolRequests
  |
  DR<:PunchSpoolRequests) ->
  (E"N:NkcpEntry(N<:CurrentNkcps &
    N.Process = DR.Process)))
&
A"N1,N2:NkcpEntry(N1<:CurrentNkcps & N2<:CurrentNkcps ->
  (N1.Process = N2.Process -> N1 = N2))
&
A"N: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))))))
&
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))))
```

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3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

transform KernelCalled(K:KernelFunction)
effect true

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

transform RD(Raddr: 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 =>
RD2b
<> RD2a)
<> R.CyclePosition = SecurityHeaderWaitForReady =>
(R.ChannelStatusWord.UnitCheck =>
RD2b
<> RD2c)
<> R.CyclePosition = Available =>
(ShuttingDown =>
KernelCalled(SendMessage(OpProcess))
<> RD1(Raddr))))

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

transform PR(Raddr: DeviceAddress)

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

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

|
P.CyclePosition<:S" (AttachedToSpoolingProcess,
AttachedToUser,DetachPending,OffLine) =>

Error

<> (P.CyclePosition = SecurityHeader =>
(P.ChannelStatusWord.UnitCheck =>

PR3b

<> PR3a)

<> P.CyclePosition = SecurityHeaderWaitForReady =>
(P.ChannelStatusWord.UnitCheck =>

PR3b

<> PR3c)

<> P.CyclePosition = Available =>
(PrinterSpoolRequests ~= Empty

&

P.State = Started

&

E"DR:OutputDeviceRequest(DR<:PrinterSpoolRequests ->
(DR.State = WaitingForDevice

&

P.ClassesServedCurrently && DR.RequestedClasses
~= Empty ->

PR2)))

<> P.CyclePosition = SecurityTrailer =>
(P.ChannelStatusWord.UnitCheck =>

PR5b

<> PR5a)

<> P.CyclePosition = SecurityTrailerWaitForReady =>
(P.ChannelStatusWord.UnitCheck =>

PR5b

<> PR5c)))

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

transform PU(Raddr: DeviceAddress)

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

effect E"P: PunchEntry(P<: 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.ChannlStatusWord.UnitCheck =>
PU3b
<> PU3c)
<> P.CyclePosition = Available =>
(PunchSpoolRequests ~ Empty
&
P.State = Started
&
E"DR: OutputDeviceRequest (DR<: PunchSpoolRequests ->
(DR.State = WaitingForDevice
&
P.ClassesServedCurrently && DR.RequestedClasses
~ Empty ->
PU2)))
<> P.CyclePosition = SecurityTrailer =>
(P.ChannelStatusWord.UnitCheck =>
PU5b
<> PU5a)
<> P.CyclePosition = SecurityTrailerWaitForReady =>
(P.ChannelStatusWord.UnitCheck =>
PU5b
<> PU5c)))

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

```
transform MsgAuth(MsgId: MsgId.  
  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 = 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 =>  
        (Nkcp(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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3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

<> Error)
<> Error))

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3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

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) <: Cat6 =>  
    OP6(MsgName(Text))  
<> MsgName(Text) = LOCATE+RADDR =>  
    (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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3.2.2 Unit Record Process (Formal)

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```

    OP10a
    <> DeviceType(Raddr(Text)) = Printer =>
    OP10b
    <> DeviceType(Raddr(Text)) = Punch =>
    OP10c
    <> DeviceType(Raddr(Text)) = TapeDrive =>
    OP10d
    <> Error)
<> MsgName(Text) = ATTACH-RADOR =>
    (DeviceType(Raddr(Text)) = Reader =>
    OP11a
    <> DeviceType(Raddr(Text)) = Printer =>
    OP11b
    <> DeviceType(Raddr(Text)) = Punch =>
    OP11c
    <> DeviceType(Raddr(Text)) = TapeDrive =>
    OP11d
    <> Error)
<> MsgName(Text) = DETACH-RADOR =>
    (DeviceType(Raddr(Text)) = Reader =>
    OP12a
    <> DeviceType(Raddr(Text)) = Printer =>
    OP12b
    <> DeviceType(Raddr(Text)) = Punch =>
    OP12c
    <> DeviceType(Raddr(Text)) = TapeDrive =>
    OP12d
    <> Error)
<> MsgName(Text) = LOADBUF =>
    (DeviceType(Raddr(Text)) = Printer =>
    OP13
    <> Error)
<> MsgName(Text) = DRAIN =>
    (DeviceType(Raddr(Text)) = Reader =>
    OP14a
    <> DeviceType(Raddr(Text)) = Printer =>
    OP14b
    <> DeviceType(Raddr(Text)) = Punch =>
    OP14c
    <> Error)
<> MsgName(Text) = START =>
    (DeviceType(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) =>
  (E"P:PendingRequest(P<:PendingRequests & P.MsgId = MsgId &
    (P.Kind = OpRequest =>
      MsgName(Text) = ResponseToOpRequest =>
        ProcessedResponse(P,MsgId,Source)
      <> Error)
    <> P.Kind = RelinquishDevice =>
      (MsgName(Text) = DetachDevice =>
        (DeviceType(Raddr(Text)) = Reader =>
          NKCP1a
          <> DeviceType(Raddr(Text)) = Printer =>
            NKCP1b
          <> DeviceType(Raddr(Text)) = Punch =>
            NKCP1c
          <> DeviceType(Raddr(Text)) = TapeDrive =>
            NKCP1d
          <> Error)
        <> Error)
      <> Error))
    <> /* message is not a response, but a request */
      (MsgName(Text) = DetachSpoolDevice =>
        (DeviceType(Raddr(Text)) = Reader =>
          RD4
          <> DeviceType(Raddr(Text)) = Printer =>
            PR4
          <> DeviceType(Raddr(Text)) = Punch =>
            PU4
          <> 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)
          <> MsgName(Text) = NeedSpoolingDevice =>
            (DeviceType(Raddr(Text)) = Printer =>
              PR1
              <> DeviceType(Raddr(Text)) = Punch =>
                PU1
              <> Error)
            <> Error))
    <> Error))
  )

```

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3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6862/181/00

```
transform URDriver(InterruptType: ,
                  InterruptSubType: ,
                  Raddr: DeviceAddress,
                  MsgId: 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(MsgId, Text, Source)
      <> Source = OpProcess =>
        MsgOp(MsgId, Text, Source)
      <> Source ~: TrustedProcesses =>
        MsgNkcp(MsgId, Text, Source)
      <> Error)
    <> Error)
  <> Error)
&
KernelCalled(ReceiveInterrupts)
&
KernelCalled(ReleaseCPU)
```

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)
      &
      ~ ShuttingDown

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)))
```


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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

RD2a: Expected IO interrupt signalling security header read

transform RD2a(Raddr: DeviceAddress,
Process: ProcessName)

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

&
R.State == NotSpooling
&
R.CyclePosition = SecurityHeader
&
R.ChannelStatusWord.UnitCheck = false
&
R.LineBuffer == nil)

effect E"R:ReaderEntry(R<:Readers & R.Raddr = Raddr &
(E"N:NkcpEntry(N<:CurrentNkcp &
N.Process = Process) =>
E"N:NkcpEntry(N<:CurrentNkcp & N.Process = Process &
N"Readers = Readers ~ S"(R) ||
S"(R.Raddr,

/sHs/ ((A"D:DeviceAddress(D<:N.UsableReaders -> D == R.Raddr)
|
~GrantedAccess)

&
R.State = Draining =>
Drained
<> R.State),

/sHs/ (E"D:DeviceAddress(D<:N.UsableReaders & D = R.Raddr)
&
GrantedAccess =>
AttachedToSpoolingProcess
<> Available),

/sHs/ (E"D:DeviceAddress(D<:N.UsableReaders & D = R.Raddr)
&
GrantedAccess =>
N.Process
<> URProcess),

/sHs/ (A"D:DeviceAddress(D<:N.UsableReaders -> D == R.Raddr)
|
~GrantedAccess =>
R.ClassesServedNextCycle
<> R.ClassesServedCurrently),
R.ClassesServedNextCycle,
R.ChannelStatusWord,
R.LineBuffer))

&

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3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

```
(E"D:DeviceAddress(D<:N.UsableReaders & D = R.Raddr) =>
  KernelCalled(GrantAccess)
&
  (GrantedAccess =>
    KernelCalled(SendMessage(N.Process))
  <> KernelCalled(SendMessage(OpProcess))
  &
    (R.State = Draining -> KernelCalled(
      SendMessage(OpProcess))))
  <> KernelCalled(SendMessage(OpProcess))
  &
    (R.State = Draining -> KernelCalled(
      SendMessage(OpProcess))))
<>
  N"Readers = Readers ~ S"(R) ||
  S"((R.Raddr,
    R.State,
    /###/ AttachPending,
    /###/ Process,
    R.ClassesServedCurrently,
    R.ClassesServedNextCycle,
    R.ChannelStatusWord,
    R.LineBuffer))
  &
    KernelCalled(SendMessage(AuthProcess)))
```

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

RD2b: IO Error when attempting security header read

transform RD2b(Raddr: DeviceAddress)

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

```
effect E"R:ReaderEntry (R<:Readers & R.Raddr = Raddr &
      N"Readers = Readers ~ S"(R) ||
      S"((R.Raddr,
          R.State,
          /sll#s/ SecurityHeaderWaitForReady,
          R.AttachedProcess,
          R.ClassesServedCurrently,
          R.ClassesServedNextCycle,
          R.ChannelStatusWord,
          R.LineBuffer)))
      &
      KernelCalled (SendMessage (OpProcess))
```

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

RD2c: Reader error cleared by operator (IO interrupt signalling device ready)

transform RD2c(Raddr: DeviceAddress)

refcond E"R:ReaderEntry (R<:Readers &

R.Raddr = Raddr

&

R.State ~ = NotSpooling

&

R.CyclePosition = SecurityHeaderWaitForReady

&

R.ChannelStatusWord.UnitCheck = false)

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))

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

RD3a: AuthProcess message re Nkcp creation: added

transform RD3a(Raddr: DeviceAddress)

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

&
E"N:NkcpEntry (N<:CurrentNkcp &
N.Process = R.AttachedProcess))

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

&
R.CyclePosition = AttachPending)
=> Error <>

E"N:NkcpEntry (N<:CurrentNkcp
&
N.Process = R.AttachedProcess

&
N"Readers = Readers ~ S" (R) ||

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 =>
URProcess
<> R.AttachedProcess),

/<##</ (A"D:DeviceAddress (D<:N.UsableReaders -> D == R.Raddr)

|
~GrantedAccess =>
R.ClassesServedNextCycle
<> R.ClassesServedCurrently),
R.ClassesServedNextCycle,
R.ChannelStatusWord,
R.LineBuffer))

&

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3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6862/101/00

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

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

RD3b: AuthProcess message re Nkcp creation: cannot add

transform RD3b(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) ||
S"((R.Raddr,
/sHhH/ (R.State = Draining =>
Drained
<> R.State),
/sHhH/ Available,
/sHhH/ URProcess,
/sHhH/ R.ClassesServedNextCycle,
R.ClassesServedNextCycle,
R.ChannelStatusWord,
R.LineBuffer)))
&
KernelCalled(SendMessage(OpProcess)))

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3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

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) ||
S"((R.Raddr,
/#####/ (DeviceReleased & R.State = Draining =>
Drained
<> R.State),
/#####/ (DeviceReleased =>
Available
<> R.CyclePosition),
/#####/ (DeviceReleased =>
URProcess
<> R.AttachedProcess),
R.ClassesServedCurrently,
R.ClassesServedNextCycle,
R.ChannelStatusWord,
R.LineBuffer))
&
KernelCalled (ReleaseDevice)
&
(R.State = Draining | ~Device Released =>
KernelCalled (SendMessage (OpProcess))
<> KernelCalled (SendMessage (R.AttachedProcess))))

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

OP14a: Drain (Reader)

transform OP14a(Raddr: DeviceAddress)

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) ||

S" (R.Raddr,

/set/set/ (R.CyclePosition = Available =>

Drained

<> Draining),

R.CyclePosition,

R.AttachedProcess,

R.ClassesServedCurrently,

R.ClassesServedNextCycle,

R.ChannelStatusWord,

R.LineBuffer))

&

(R.CyclePosition = Available ->

KernelCalled(SendMessage(OpProcess))))

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

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) ||

S" (R.Raddr,

/still/ (NewClasses ~ Empty

R.ClassesServedCurrently ~ Empty =>
Started

<> R.State),

R.CyclePosition,

R.AttachedProcess,

/still/ (NewClasses ~ Empty

&

R.CyclePosition = Available =>

NewClasses

<> R.ClassesServedCurrently),

/still/ (NewClasses ~ Empty =>

NewClasses

<> R.ClassesServedNextCycle),

R.ChannelStatusWord,

R.LineBuffer))

&

KernelCalled (SendMessage (OpProcess)))

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

PR1: Process request for output spooling device assignment

transform PR1 (Process: ProcessName
RequestedClasses: set of Class)

effect (A"N:NkcpEntry (N<:CurrentNkcp ->
N.Process ~ Process)

|
RequestedClasses = Empty

=> Error <>

N"PrinterSpoolRequests =

(~ShuttingDown =>

PrinterSpoolRequests ||

S" ((Process,

RequestedClasses,

nil,

WaitingForDevice))

<> PrinterSpoolRequests))

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 3.2.2 Unit Record Process (Formal)

System Development Corporation
 TM-6062/101/00

PR2: Printer Assignment (for spooling)

transform PR2 (DR: OutputDeviceRequest,
 P: PrinterEntry)

refcond DR<:PrinterSpoolRequests

```

&
P<:Printers
&
P.State = Started
&
P.CyclePosition = Available
&
DR.State = WaitingForDevice
&
ClassesMatch(P.ClassesServedCurrently,
DR.RequestedClasses)
&
E"N:NkcpEntry(N<:CurrentNkcps &
N.Process = DR.Process)

```

effect E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr &
 (E"N:NkcpEntry(N<:CurrentNkcps & N.Process = DR.Process &
 N"Printers = Printers ~ S"(P) ||

```

S"((P.Raddr,
P.State,
/%%/ (E"D:DeviceAddress(D<:N.UsablePrinters & D = P.Raddr) =>
SecurityHeader
<> P.CyclePosition),
/%%/ (E"D:DeviceAddress(D<:N.UsablePrinters & D = P.Raddr) =>
DR.Process
<> P.AttachedProcess),
P.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.RelinquishDeviceRequestState,
P.ChannelStatusWord))

```

```

&
N"PrinterSpoolRequests = PrinterSpoolRequests ~ S"(DR) ||
S"((DR.Process,
DR.RequestedClasses,

```

```

/%%/ (E"D:DeviceAddress(D<:N.UsablePrinters & D = P.Raddr) =>
P.Raddr
<> DR.AttachedDevice)
/%%/ (E"D:DeviceAddress(D<:N.UsablePrinters & D = P.Raddr) =>
Processing
<> DR.State)))

```

```

&
KernelCalled(RequestIO(P.Raddr)))

```

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

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,

/s#s#s/

(GrantedAccess =>

AttachedToSpoolingProcess

<> SecurityTrailer),

P.AttachedProcess,

P.ClassesServedCurrently,

P.ClassesServedNextCycle,

/s#s#s/

(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)))

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

PR3b: Interrupt, IO 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) ||
    S"((P.Raddr,
    /###/ P.State,
    SecurityHeaderWaitForReady,
    P.AttachedProcess,
    P.ClassesServedCurrently,
    P.ClassesServedNextCycle,
    P.RelinquishDeviceRequestState,
    P.ChannelStatusWord))
```

```
&
    KernelCalled(SendMessage(OpProcess)))
```

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

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) ||
    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)

System Development Corporation
TM-6062/101/00

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) ||
S"((P.Raddr,
  P.State,
  SecurityTrailer,
  URProcess,
  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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3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

PRSa: Interrupt indicating successful completion of security trailer

transform PRSa(Raddr: DeviceAddress)

```
refcond 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) ||
    S"((P.Raddr,
    /settle/ (P.State = Draining =>
        Drained
        <> P.State),
    /settle/ Available,
    /settle/ P.AttachedProcess,
    /settle/ P.ClassesServedNextCycle,
    /settle/ P.ClassesServedNextCycle,
    /settle/ NoNeed,
    P.ChannelStatusWord)))
```

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 3.2.2 Unit Record Process (Formal)

System Development Corporation
 TM-6062/101/00

PR5b: Interrupt. IO error on security trailer output

```

transform PR5b(Raddr: DeviceAddress)
refcond E"P:PrinterEntry (P<:Printers &
    P.Raddr = Raddr
    &
    P.State ~ NotSpooling
    &
    P.CyclePosition<:S" (SecurityTrailer,
                                SecurityTrailerWaitForReady)
    &
    P.ChannelStatusWord.UnitCheck = true)
effect E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr &
    N"Printers = Printers ~ S" (P) ||
    S" (P.Raddr,
    P.State,
    /x##x/ SecurityTrailerWaitForReady,
    P.AttachedProcess,
    P.ClassesServedCurrently,
    P.ClassesServedNextCycle,
    P.RelinquishDeviceRequestState,
    P.ChannelStatusWord))
    &
    KernelCalled(SendMessage(OpProcess)))
  
```

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

PR5c: Interrupt, OK to retry security trailer output

transform PR5c(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 &

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

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)

System Development Corporation
TM-6062/101/00

PU1: Process request for output spooling device assignment

transform PU1 (Process: ProcessName
RequestedClasses: set of Class)

effect (A"N:NkcpEntry (N<:CurrentNkcp ->
N.Process == Process)

|
RequestedClasses = Empty

=> Error <>

N"PunchSpoolRequests =

(~ShuttingDown =>

PunchSpoolRequests ||

S"((Process,

RequestedClasses,

nil,

WaitingForDevice))

<> PunchSpoolRequests)

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3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

PU2: Punch Assignment (for spooling)

transform PU2 (DR: OutputDeviceRequest,
P: PunchEntry)

refcond DR<:PunchSpoolRequests

&
P<:Punches
&
P.State = Started
&
P.CyclePosition = Available
&
DR.State = WaitingForDevice
&
ClassesMatch(P.ClassesServedCurrently,
DR.RequestedClasses)
&
E"N:NkcpEntry (N<:CurrentNkcps &
N.Process = DR.Process)

effect E"P:PunchEntry (P<:Punches & P.Raddr = Raddr &
(E"N:NkcpEntry (N<:CurrentNkcps & N.Process = DR.Process &
N"Punches = Punches ~ S" (P) ||
S" ((P.Raddr,
P.State,
/sHs/ (E"D:DeviceAddress (D<:N.UsablePunches & D = P.Raddr) =>
SecurityHeader
<> P.CyclePosition),
/sHs/ (E"D:DeviceAddress (D<:N.UsablePunches & D = P.Raddr) =>
DR.Process
<> P.AttachedProcess),
P.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.RelinquishDeviceRequestState,
P.ChannelStatusWord))
&
N"PunchSpoolRequests = PunchSpoolRequests ~ S" (DR) ||
S" ((DR.Process,
DR.RequestedClasses,
/sHs/ (E"D:DeviceAddress (D<:N.UsablePunches & D = P.Raddr) =>
P.Raddr
<> DR.AttachedDevice)
/sHs/ (E"D:DeviceAddress (D<:N.UsablePunches & D = P.Raddr) =>
Processing
<> DR.State)))
&
KernelCalled (RequestIO (P.Raddr))))

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"Punches = Punches ~ 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))))
```

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

PU3b: Interrupt. IO error on attempt to output security header

transform PU3b(Raddr: DeviceAddress)

```
refcond 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) ||
    S"((P.Raddr,
        P.State,
        /* SecurityHeaderWaitForReady,
        P.AttachedProcess,
        P.ClassesServedCurrently,
        P.ClassesServedNextCycle,
        P.RelinquishDeviceRequestState,
        P.ChannelStatusWord))
    &
    KernelCalled(SendMessage(OpProcess)))
```

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

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.CyclePosition = SecurityHeaderWaitForReady
    &
    P.ChannelStatusWord.UnitCheck = false)
```

```
effect E"P:PunchEntry(P<:Punches & P.Raddr = Raddr &
    N"Punches = Punches ~ S"(P) ||
    S"((P.Raddr,
    /sdhhd/ P.State,
    SecurityHeader,
    P.AttachedProcess,
    P.ClassesServedCurrently,
    P.ClassesServedNextCycle,
    P.RelinquishDeviceRequestState,
    P.ChannelStatusWord))
    &
    KernelCalled(RequestIO(P.Raddr)))
```


21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

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"DR:OutputDeviceRequest(DR<:PunchSpoolRequests &
          DR.Process = P.AttachedProcess
          &
          DR.State = Processing
          &
          DR.AttachedDevice = P.Raddr)))
      => Error <>
      N"Punches = Punches ~ S"(P) ||
      S"((P.Raddr,
        P.State,
        SecurityTrailer,
        URProcess,
        P.ClassesServedCurrently,
        P.ClassesServedNextCycle,
        P.RelinquishDeviceRequestState,
        P.ChannelStatusWord))
      &
      E"DR:OutputDeviceRequest(DR<:PunchSpoolRequests &
        DR.Process = P.AttachedProcess
        &
        DR.State = Processing
        &
        DR.AttachedDevice = P.Raddr
        &
        N"PunchSpoolRequests =
          PunchSpoolRequests ~ S"(DR))
      &
      KernelCalled(RequestIO(P.Raddr)))
```

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

PUSa: Interrupt indicating successful completion of security trailer

transform PUSa(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) ||
    S"((P.Raddr,
    /s###/ (P.State = Draining =>
        Drained
        <> P.State),
    /s###/ Available,
    P.AttachedProcess,
    /s###/ P.ClassesServedNextCycle,
    P.ClassesServedNextCycle,
    /s###/ NoNeed,
    P.ChannelStatusWord)))
```

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

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<:S" (SecurityTrailer,

SecurityTrailerWaitForReady)

&

P.ChannelStatusWord.UnitCheck = true)

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

N"Punches = Punches ~ S"(P) ||

S"((P.Raddr,

P.State,

/x##x/

SecurityTrailerWaitForReady,

P.AttachedProcess,

P.ClassesServedCurrently,

P.ClassesServedNextCycle,

P.RelinquishDeviceRequestState,

P.ChannelStatusWord))

&

KernelCalled(SendMessage(OpProcess))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

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)
```

```
effect E"P:PunchEntry(P<:Punches & P.Raddr = Raddr &
    N"Punches = Punches ~ S"(P) ||
    S'((P.Raddr,
    /s###/ P.State,
    SecurityTrailer,
    P.AttachedProcess,
    P.ClassesServedCurrently,
    P.ClassesServedNextCycle,
    P.RelinquishDeviceRequestState,
    P.ChannelStatusWord))
    &
    KernelCalled(RequestIO(P.Raddr)))
```

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

OP14b: Drain (Printer)

transform OP14b(Raddr: DeviceAddress)

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) ||

S"(P.Raddr,

/sH#s/ (P.CyclePosition = Available =>
Drained

<= Draining),

P.CyclePosition,

P.AttachedProcess,

P.ClassesServedCurrently,

P.ClassesServedNextCycle,

/sH#s/ (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) ||
    S"((P.Raddr,
    /s###/ (P.CyclePosition = Available =>
        Drained
        <> Draining),
        P.CyclePosition,
        P.AttachedProcess,
        P.ClassesServedCurrently,
        P.ClassesServedNextCycle,
    /s###/ (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))))
  
```

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

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) ||

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.ChannelStatusWord))

&

KernelCalled(SendMessage(OpProcess))

&

(NewClasses ~ Empty

&

P.CyclePosition = AttachedToSpoolingProcess

&

P.RelinquishDeviceRequestState ~ Sent ->

KernelCalled(SendMessage(P.AttachedProcess))))))

21 May 1978
 3.2.2 Unit Record Process (Formal)

System Development Corporation
 TM-6062/101/00

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.ChannelStatusWord))
 &
 KernelCalled(SendMessage(OpProcess))
 &
 (NewClasses ~ Empty
 &
 P.CyclePosition = AttachedToSpoolingProcess
 &
 P.RelinquishDeviceRequestState ~ Sent ->
 KernelCalled(SendMessage(P.AttachedProcess))))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

OP0: Miscellaneous commands

commands:

QUERY+UR
QUERY+ALL
QUERY+RADOR
QUERY+TAPES

transform OP0(Command: CommandName)

refcond Command<:Cat0

effect KernelCalled(SendMessage(OpProcess))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6862/101/88

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<:Cat1

effect N"PendingRequests = PendingRequests ||
 S"((NewMsgId,
 OpRequest,
 Command,
 S"((Destination(Command),
 nil,
 NoResponse))))

&
KernelCalled(SendMessage(Destination(Command)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6862/101/00

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 ||
S"((NewMsgId,
OpRequest,
Command,
S"R:ResponseSlot(E"N:ProcessName
(N<:CurrentNkcp &
R = (N,nil,NoResponse))))

&

A"N:ProcessName (N<:CurrentNkcp ->
KernelCalled(SendMessage(N))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

OP3: Single message sent
 Mapping: User id -> Nkcp 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"((NewMagId,
 MapUserId,
 Command,
 S"((AuthProcess,
 nil,
 NoResponse))))
 &
 KernelCalled(SendMessage(AuthProcess))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6862/101/00

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)))

21 May 1978
3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

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 ||
S"((NewMsgId,
OpRequest,
Command,
S"((P.AttachedProcess,
nil,
NoResponse))))
&
KernelCalled(SendMessage(P.AttachedProcess)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

```
OPS:    command:
        SPACE

transform OPS(Command: CommandName,
              Raddr: DeviceAddress)

refcond Command = SPACE
&
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)))
```

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

OP6: commands:

ORDER←SYSTEM
PURGE←SYSTEM

transform OP6(Command: CommandName,
Nkcps: set of ProcessName)

refcond Command←CommandName

&
A"N:ProcessName(N←Nkcps →
E"CN:NkcpEntry
(CN←CurrentNkcps
&
CN.Process = N))

effect N"PendingRequests = PendingRequests ||
S"((NewMsgid,
OpRequest,
Command,
S"R:ResponseSlot(E"N:ProcessName
(N←Nkcps
&
R = (N,nil,NoResponse))))))
&
A"N:ProcessName(N←Nkcps →
KernelCalled(SendMessage(N)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

OP7a: LOCATE of Reader

transform OP7a(Command: CommandName,
Raddr: DeviceAddress)

refcond Command = LOCATE+RADDR

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

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

=> Error <>

N"PendingRequests = PendingRequests ||

S"((NewMsgId,

OpRequest,

Command,

S"((R.AttachedProcess,

nil,

NoResponse))))

&

KernelCalled(SendMessage(D.AttachedProcess)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6862/101/00

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 ~<:S"(AttachedToSpoolingProcess,
AttachedToUser)

=> Error <>

N"PendingRequests = PendingRequests ||

S"((NewMagId,
OpRequest,
Command,
S"((P.AttachedProcess,
nil,
NoResponse))))

&

Kerne!Called(SendMessage(P.AttachedProcess)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-5062/101/80

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 ||
S"((NewMsgid,
OpRequest,
Command,
S"((P.AttachedProcess,
nil,
NoResponse))))

&
KernelCalled(SendMessage(P.AttachedProcess)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

OP7d: LOCATE of Tape Drive

transform OP7d(Command: CommandName,
Raddr: DeviceAddress)

refcond Command = LOCATE←RADDR

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

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

21 May 1978
3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

OP8: command:
 SHUTDOWN

transform OP8(Command: CommandName)

refcond Command = SHUTDOWN

effect N"ShuttingDown = true

 &

 N"PrinterSpoolRequests = PrinterSpoolRequests --
 S"DR:OutputDeviceEntry(
 DR.State = WaitingForDevice)

 &

 N"PunchSpoolRequests = PunchSpoolRequests --
 S"DR:OutputDeviceEntry(
 DR.State = WaitingForDevice)

21 May 1978
 3.2.2 Unit Record Process (Formal) System Development Corporation
 TM-6062/101/00

OP9a: Very offline (Reader)

transform OP9a(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) ||
 S"(R.Raddr,

/#####/
 /#####/
 NotSpooling,
 OffLine,
 R.AttachedProcess,
 R.ClassesServedCurrently,
 R.ClassesServedNextCycle,
 R.ChannelStatusWord,
 R.LineBuffer))

&
 KernelCalled(SendMessage(OpProcess)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/181/88

OP9b: Vary offline (Printer)

transform OP9b(Command: CommandName,
Raddr: DeviceAddress)

refcond Command = VARY-OFFLINE

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

effect E"P:PrinterEntry(P:P:Printers & P.Raddr = Raddr &
(P.CyclePosition ~<:S"(Available,OffLine)
=> Error <>

N"Printers = Printers ~ S"(P) ||
S"((P.Raddr,

/***/
/***/
NotSpooling,
OffLine,
P.AttachedProcess,
P.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.RelinquishDeviceRequestState,
P.ChannelStatusWord)

&

KernelCalled(SendMessage(OpProcess)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6862/101/00

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) ||
S"((P.Raddr,

/***/ NotSpooling,
/***/ OffLine,
P.AttachedProcess,
P.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.RelinquishDeviceRequestState,
P.ChannelStatusWord!)

&
KernelCalled(SendMessage(DpProcess)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6862/101/00

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) ||

S"((T.Raddr,
/*** OffLine,
T.AttachedProcess))

&
KernelCalled(SendMessage(OpProcess)))

21 May 1978
 3.2.2 Unit Record Process (Formal)

System Development Corporation
 TM-6062/101/00

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) ||
  S" ((R.Raddr,
    /<###>/ Drained,
    /<###>/ Available,
    /<###>/ URProcess,
    /<###>/ R.ClassesServedNextCycle,
    R.ClassesServedNextCycle,
    R.ChannelStatusWord,
    R.LineBuffer))
  &
  KernelCalled(SendMessage(OpProcess)))
  
```

21 May 1978
3.2.2 Unit Record Process (Form1)

System Development Corporation
TM-6062/101/00

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"Printers = Printers ~ S" (P) ||

S" (P.Raddr,

/s###/ Drained,

/s###/ Available,

/s###/ URProcess,

/s###/ P.ClassesServedNextCycle,

P.ClassesServedNextCycle,

/s###/ NoNeed,

P.ChannelStatusWord))

&

KernelCalled(SendMessage(OpProcess)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/161/80

OP10c: Vary online (Punch)

transform OP10c (Command: CommandName,
Raddr: DeviceAddress)

refcond Command = VARY-ONLINE

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

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

&
P.CyclePosition = OffLine)

=> Error <>

N"Punches = Punches ~ S"(P) ||

S"((P.Raddr,

/x###/ Drained,
/x###/ Available,
/x###/ URProcess,
/x###/ P.ClassesServedNextCycle,
/x###/ P.ClassesServedNextCycle,
/x###/ NoNeed,
P.ChannelStatusWord))

&

KernelCalled (SendMessage (OpProcess)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6862/101/08

OP10d: Vary online (Tape Drive)

transform OP10d(Command: CommandName,
Raddr: DeviceAddress)

re:cond 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))

&

KernelCalled(SendMessage(OpProcess)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

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:NkcpEntry (N<:CurrentNkcps ->
N.Process == Process)
=> Error <>
N"Readers = Readers ~ S"(R) ||
S"((R.Raddr,
/all/ (R.State=Drained
&
R.CyclePosition=Available
&
GrantedAccess=>
NotSpooling
<> R.State),
/all/ (R.State=Drained
&
R.CyclePosition=Available
&
GrantedAccess=>
AttachedToUser
<> R.CyclePosition),
/all/ (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)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-5862/101/00

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

transform AUTH3b(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<:CurrentNkcp ->
N.Process == Process)

=> 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.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.RelinquishDeviceRequestState,
P.ChannelStatusWord))

&

(R.State=Drained

&

P.CyclePosition=Available->
KernelCalled(GrantAccess(P.Raddr)))

&

KernelCalled(SendMessage(AuthProcess)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6862/101/00

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) ||
                        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.ClassesServedCurrently,
          P.ClassesServedNextCycle,
          P.RelinquishDeviceRequestState,
          P.ChannelStatusWord))
&
          (R.State=Drained
          &
          P.CyclePosition=Available->
            KernelCalled(GrantAccess(P.Raddr)))
&
          KernelCalled(SendMessage(AuthProcess)))
```


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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6862/181/28

AUTH3d: Attach tape drive (request from AuthProcess)

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

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

effect E"T:TapeDriveEntry(T<:TapeDrives & T.Raddr = Raddr &
(A"N:NkcpEntry (N<:CurrentNkcp ->
N.Process == Process)
=> Error <>
N"TapeDrives = TapeDrives ~ S"(T) ||
S"((T.Raddr,
/s###/ (T.State=Available
&
GrantedAccess=>
AttachedToUser
<> T.State),
/s###/ (T.State=Available
&
GrantedAccess=>
Process
<> T.AttachedProcess)))
&
KernelCalled(SendMessage(AuthProcess)))

3.2.2 Unit Record Process (Formal)

TM-6862/101/00

```
transform OP11a(Raddr: DeviceAddress,  
               Process: ProcessName)
```

```

effect E"R:ReaderEntry(R<:Readers & R.Raddr = Raddr &
(A"N:NkcpEntry(N<:CurrentNkcps ->
N.Process ~ Process)

```

```

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.ClassesServedCurrently,
R.ClassesServedNextCycle,
R.ChannelStatusWord,
R.LineBuffer))

```

Kernel Called (SendMessage (OpProcess))

```

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

```

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

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) ||
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.ClassesServedCurrently,
P.ClassesServedNextCycle,
P.RelinquishDeviceRequestState,
P.ChannelStatusWord))
&
KernelCalled(SendMessage(OpProcess))
&
(P.State=Drained
&
P.CyclePosition=Available->
(KernelCalled(GrantAccess(P.Raddr))
&
(GrantedAccess ->
KernelCalled(SendMessage(Process))))))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6862/101/00

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

transform OP11c(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<:CurrentNkcp ->
N.Process == Process)

=> Error <>

N"Punches = Punches ~ 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.ClassesServedCurrently,

P.ClassesServedNextCycle,

P.RelinquishDeviceRequestState,

P.Channel(StatusWord))

&

KernelCalled(SendMessage(OpProcess))

&

(P.State=Drained

&

P.CyclePosition=Available->

(KernelCalled(GrantAccess(P.Raddr))

&

(GrantedAccess ->

KernelCalled(SendMessage(Process))))))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

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,
DetachPending,
R.AttachedProcess,
R.ClassesServedCurrently,
R.ClassesServedNextCycle,
R.ChannelStatusWord,
R.LineBuffer))

&

N"PendingRequests = PendingRequests ||

S"((NewMsgId,

RelinquishDevice,

Undefined,

S"((R.AttachedProcess,

nil,

NoResponse))))))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

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) ||

S"((P.Raddr,

/###/

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

&

N"PendingRequests = PendingRequests ||

S"((NewMagId,

RelinquishDevice,
Undefined,

S"((P.AttachedProcess,

nil,

NoResponse))))))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6862/101/00

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) ||

S"((P.Raddr,
P.State,

/***/

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

&

N"PendingRequests = PendingRequests ||

S"((NewMagId,

RelinquishDevice,
Undefined,

S"((P.AttachedProcess,
nil,
NoResponse))))))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

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 <>

N"Readers = Readers ~ S"(R) ||

S"(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)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

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.State = NotSpooling

&
P.CyclePosition = AttachedToUser
&
P.AttachedProcess = Process)

=> Error <>

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

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)))

21 May 1978
3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

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) ||  
    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(LpProcess)))
```

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/181/88

OP12d: Detach dedicated device from user (request from operator)
(Tape Drive)

transform OP12d(Raddr: DeviceAddress,
Process: ProcessName)

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

effect E":TapeDriveEntry(T<:TapeDrives & T.Raddr = Raddr &
(~(T.State=Attached
&
T.AttachedProcess=Process)
=> Error <>
N"TapeDrives = TapeDrives ~ S"(T) ||
S"((T.Raddr,
/###/ DetachPending,
T.AttachedProcess))
&
N"PendingRequests = PendingRequests ||
S"((NewMagId,
RelinquishDevice,
Undefined,
S"((T.AttachedProcess,
nil,
NoResponse))))))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/181/00

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) ||
                           S"((T.Raddr,
                               /***/ (DeviceReleased=>
                                   Available
                                   <> T.State),
                               /***/ (DeviceReleased=>
                                   URProcess
                                   <> T.AttachedProcess)))
                           &
                           KernelCalled(ReleaseDevice(T.Raddr))
                           &
                           KernelCalled(SendMessage(T.AttachedProcess))
                           &
                           KernelCalled(SendMessage(OpProcess))))
```

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-5862/101/88

NKCP1a: Process message, relinquishing device as requested
(Reader)

```
transform NKCP1a(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 = DetachPending
    &
    R.AttachedProcess = Process)
    => Error <>
    N"Readers = Readers ~ S"(R) ||
    S"(R.Raddr,
    /x##x/ (DeviceReleased=>
    Drained
    <> R.State),
    /x##x/ (DeviceReleased=>
    Available
    <> R.CyclePosition),
    /x##x/ (DeviceReleased=>
    URProcess
    <> R.AttachedProcess),
    R.ClassesServedCurrently,
    R.ClassesServedNextCycle,
    R.ChannelStatusWord,
    R.LineBuffer))
    &
    KernelCalled!ReleaseDevice(R.Raddr))
    &
    KernelCalled(SendMessage(R.AttachedProcess))
    &
    KernelCalled(SendMessage(OpProcess)))
```

21 May 1978
3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/181/88

NKCP1b: Process message, relinquishing device as requested
(Printer)

transform NKCP1b(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 = DetachPending
&
P.AttachedProcess = Process)

=> Error <>

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

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)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

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) ||

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)))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

OP13: Loadbuf

transform OP13(Raddr: DeviceAddress)

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

effect E"P:PrinterEntry(P<:Printers & P.Raddr = Raddr &
(~(P.State = Drained
&
P.CyclePosition = Available)
=> Error <>
true))

21 May 1978

3.2.2 Unit Record Process (Formal)

System Development Corporation
TM-6062/101/00

NKCP1d: Process message, relinquishing device as requested (Tape Drive)

transform NKCP1d(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) ||
S"((T.Raddr,
/*##*/ (DeviceReleased=>
Available
<> T.State)
/*##*/ (DeviceReleased=>
URProcess
<> T.AttachedProcess)))

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

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:NkcpEntry (N<:CurrentNkcpes ->
 N.Process ~ Process)
 => Error <>
 E"N:NkcpEntry(N<:CurrentNkcpes &
 N.Process=Process
 &
 N"TapeDrives = TapeDrives ~ S"(T) ||
 S"((T.Raddr,
 /***/ (T.Raddr<:N.UsableTapeDrives
 &
 T.State=Available
 &
 CheckedSecLevel
 &
 GrantedAccess=>
 Attached
 <> T.State),
 /***/ (T.Raddr<:N.UsableTapeDrives
 &
 T.State=Available
 &
 CheckedSecLevel
 &
 GrantedAccess=>
 N.Process
 <> T.AttachedProcess)))
 &

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6862/101/88

```
&
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)

System Development Corporation
TM-6062/101/00

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)))
```

AUTH2: Delete Nkcp

```

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

```

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3.2.2 Unit Record Process (Formal)

System Development Corporation

TM-6062/101/00

KERN1: message from Kernel, re device availability (during scan at system initialization)

transform KERN1 (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) ||
          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) ||
                S"((P.Raddr,
                  />>>/ NotAvailableForSpooling,
                  />>>/ OffLine,
                    P.AttachedProcess,
                    P.ClassesServedCurrently,
                    P.ClassesServedNextCycle,
                    P.RelinquishDeviceRequestState,
                    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) ||
                      S"((P.Raddr,
                        />>>/ NotAvailableForSpooling,
                        />>>/ OffLine,
                          P.AttachedProcess,
                          P.ClassesServedCurrently,
                          P.ClassesServedNextCycle,
                          P.RelinquishDeviceRequestState,
                          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) ||
                            S"((T.Raddr,
                              />>>/ OffLine,
                              T.AttachedProcess))
                              <> Error)))
                          <> Error)))
end URProcess
```

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3.3.1 Authorization Process (Informal)

System Development Corporation

TM-6062/101/00

3.3.1: Authorization Process Informal Description

This section contains the informal description of the Authorization Process of KVM/370.

Overview

The Authorization Process performs several functions of major importance to the system security of KVM/370. 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.

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3.3.1 Authorization Process (Informal)

System Development Corporation

TM-6062/101/00

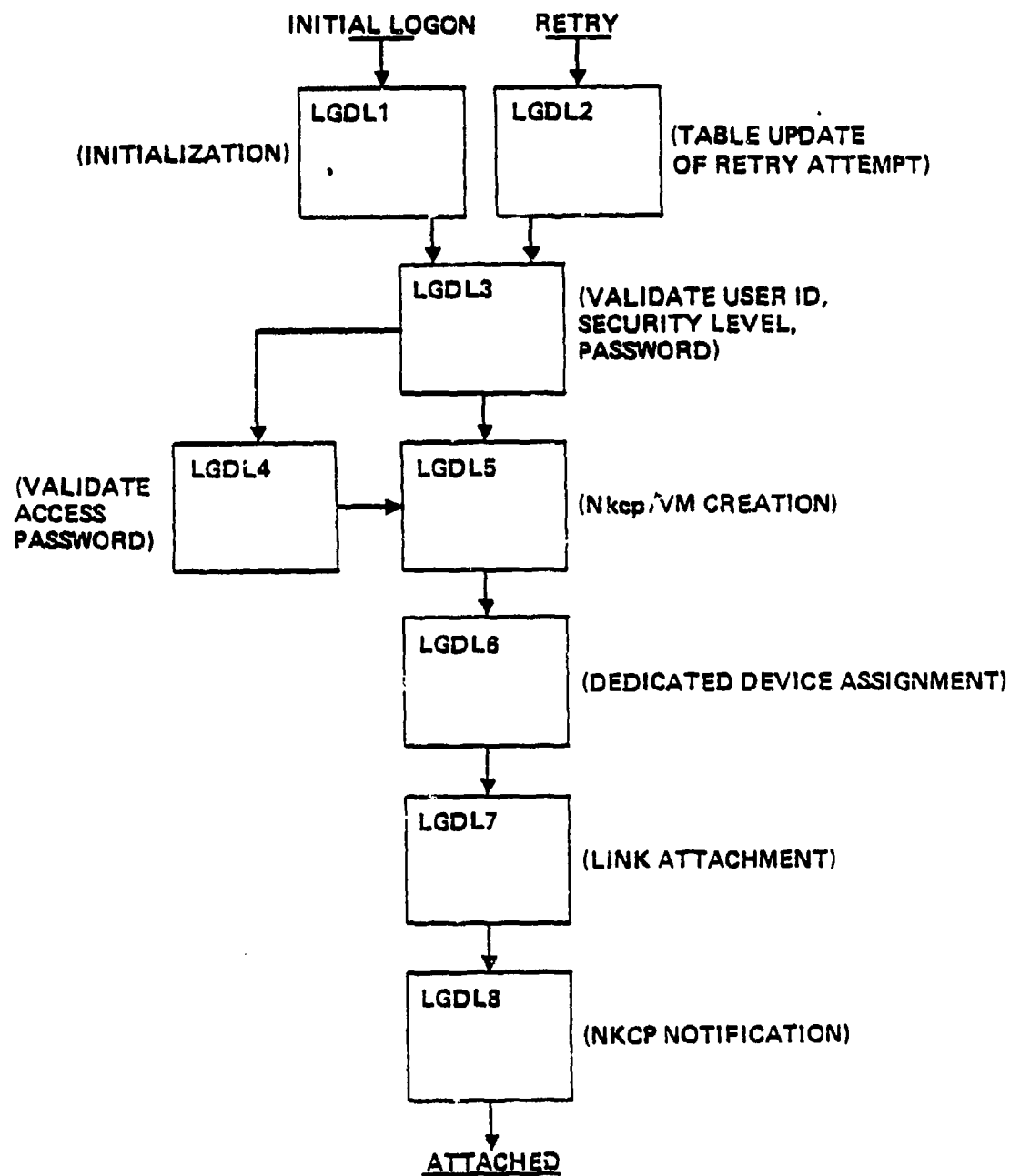


Figure 4

THE ATTACH VALIDATION SEQUENCE
(PROCESS STRUCTURE)

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3.3.1 Authorization Process (Informal)

System Development Corporation

TM-6062/101/00

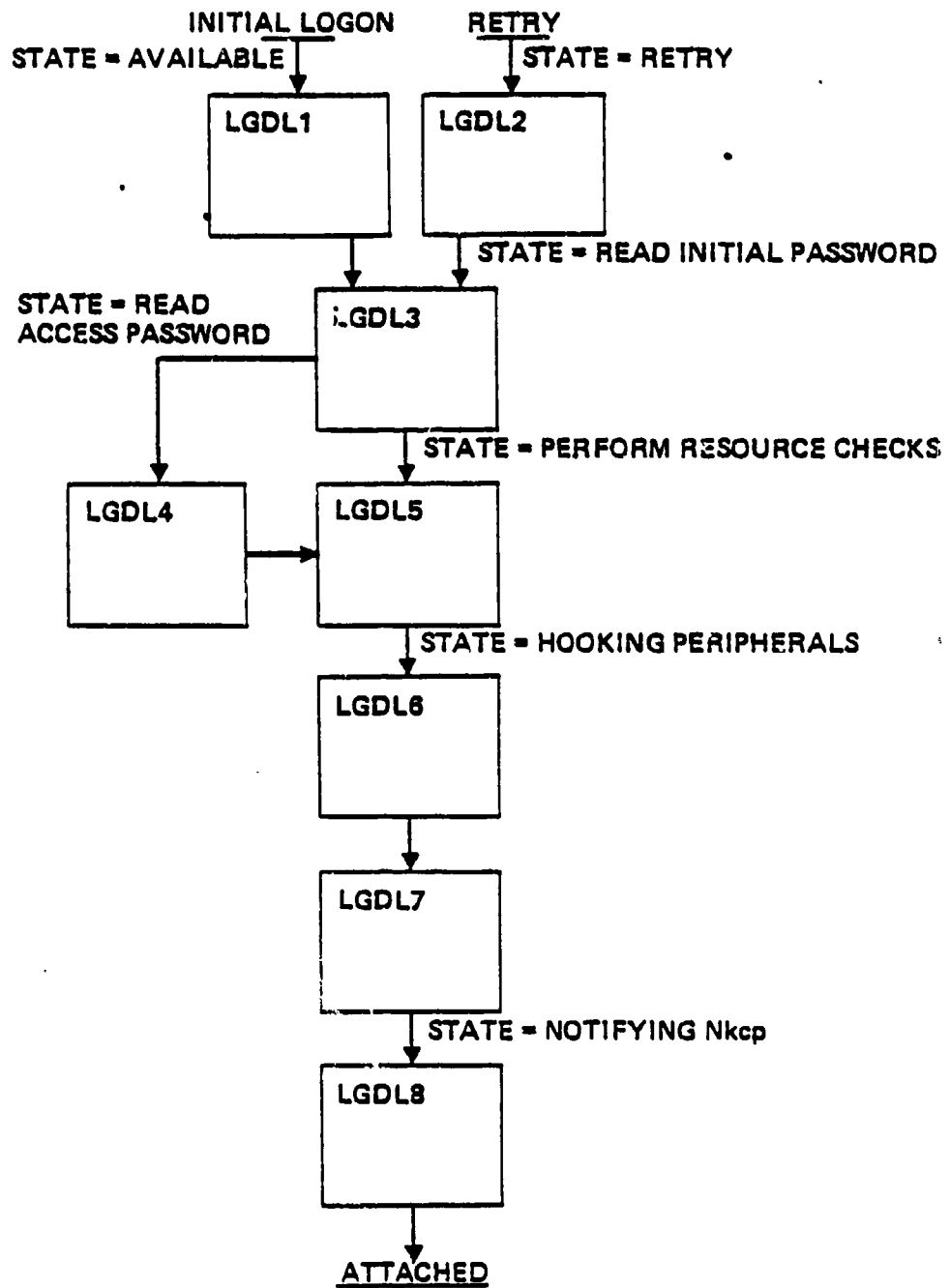


Figure 5
The Attach Validation Sequence
(State Transitions)

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3.3.1 Authorization Process (Informal)

System Development Corporation

TM-6062/101/00

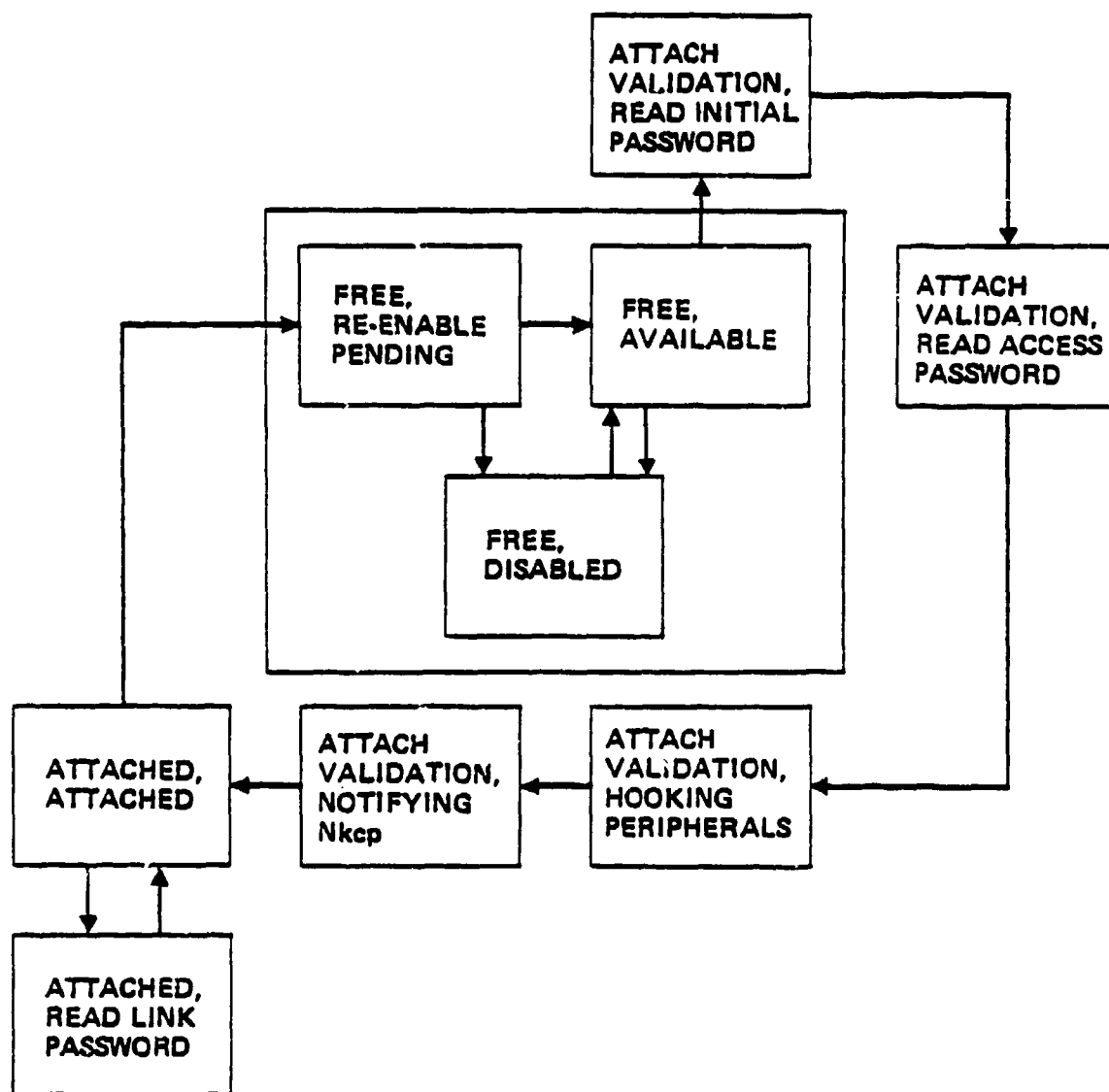


Figure 6

The Line Activity Cycle

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3.3.1 Authorization Process (Informal)

System Development Corporation

TM-6062/101/00

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.

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3.3.1 Authorization Process (Informal)

System Development Corporation

TM-6062/181/88

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.

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3.3.1 Authorization Process (Informal)

System Development Corporation

TM-6062/101/00

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.

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3.3.1 Authorization Process (Informal)

System Development Corporation

TM-6862/101/00

Operator Process
- Requests -

AUTOLOG

QUERY

DASD -

LINES -

GRAF -

SYSTEM -

NAMES -

USERS -

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)

System Development Corporation

TM-6062/101/00

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

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

3.3.2: Authorization Process
Formal Specification

```
module AuthProcess
type
DeviceAddress,
LineAddress,
ProcessName,
Virt. MachineName,
Volume..J.
```

```
CommandName = (AUTOLOG, ATTACH+RADDR, DETACH+RADDR, VARY+ONLINE,
VARY+OFFLINE, QUERY+DASD, 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+DASD, 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(VolumeId): T"I:integer(0<I),
Raddr(String): DeviceAddress,
Laddr(String): DeviceAddress,
MsgName(String): MessageNames,
OpProcess, URProcess, NetworkProcess, AuthProcess: ProcessName,
TrustedProcesses: S"(OpProcess, URProcess, AuthProcess)
```

```
constant
AddressSpaceSize: T"I:integer(0<=I & I<=8191),
CodeSize: T"I:integer(0<=I & I<=8191),
Code: integer,
#MaxCylinders: T"I:integer(I>0),
#MaxRetries: T"I:integer(I>=0),
#MaxNkcps: T"I:integer(I>=0),
#MaxVMe: T"I:integer(I>=0)
```


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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6362/101/00

type
RequestCategory = (Attach, ClearLine, ReDirectLine, WriteAndReadLine,
OpRequest, NewVM, ConnectVM, NewUser,
NewOrConnectedVM, RelinquishDevice),
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, MW),
LineCondition = T (Disabled, Available),
ActivityStatus = (Free, Attached, AttachValidation),
AccessCategory = (Logon, Dial),
ReasonTypes = (IncorrectLogon, ResourceFailure, SecurityViolation,
MaxThresholdExceeded, NoNkcp, NoVM, 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,
 IpIDefined = boolean,
 AccessPasswords = set of AccessPasswordEntry),

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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3.3.2 Authorization Process (Formal)

System Development Corporation
TM- J62/101/00

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

SharableDriveEntry = structure of (
 Raddr = DeviceAddress,
 State = SharableDriveStatus,
 SecLevel = ProcessName,
 MountedVolume = VolumeId),

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

MiniDiskEntry = structure of (
 MDName = MiniDiskName,
 ContainingVolume = VolumeId,
 Cylinders = T"I:integer(1<=I & I<=#MaxCylinders) >>
 T"I:integer(1<=I & I<=#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,
 State = ResponseStatus),

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

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/181/00

variable

#Nkcps: NkcpRange,

#VMs: VMRange,

#Users: UserRange,

ShuttingDown: 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

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```
initial
#Nkcps = 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
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6962/101/00

```
Invariant
#Nkcps <= #MaxNkcps
&
#VMs <= #MaxVMs
&
#Users <= #MaxUsers
&
InvariantsOfURPOwnedDevices
&
InvariantsOfNonsharableDrives
&
InvariantsOfSharableDrives
&
InvariantsOfSharedVolumes
&
InvariantsOfMiniDisks
&
InvariantsOfCurrentNkcps
&
InvariantsOfLines
&
InvariantsOfPendingRequests
&
InvariantsOfUserDirectory
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

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))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

InvariantsOfNonsharableDrives =

```
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:NkcpEntry(N<:CurrentNkcp &  
            N.Process = NS.AttachedProcess  
            &  
            Dominates(NS.MaxSecLevel,N.Process)  
            &  
            Dominates(N.Process,NS.MinSecLevel)  
            &  
            E*A:AttachedDeviceEntry(A<:N.AttachedDevices &  
                A.Raddr = NS.Raddr))))
```


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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

InvariantsOfSharableDrives =

A"S1,S2:SharableDriveEntry(S1<:SharableDrives & S2<:SharableDrives ->
(S1.Raddr = S2.Raddr -> S1 = S2))

&

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

System Development Corporation
TM-6062/101/00

```

A"V1,V2:SharedVolumeEntry(V1<:SharedVolumes & V2<:SharedVolumes ->
  (V1.Volume = V2.Volume -> V1 = V2))
&
A"V:SharedVolumeEntry(V<:SharedVolumes ->
  (V.State = Mounted ->
    E"S:SharableDriveEntry(S<:SharableDrives &
      S.Raddr = V.MountedDevice
      &
      S.MountedVolume = V.Volume
      &
      S.State = AttachedToSystem
      &
      Dominates(S.SecLevel,V.SecLevel))))

```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

InvariantsOfMiniDisks =

A*M1,M2:MiniDiskEntry(M1<:MiniDisks & M2<:MiniDisks ->
(M1.MDName = M2.MDName -> M1 = M2))

&

A*M:MiniDiskEntry(M<:MiniDisks ->

E"V:SharedVolumeEntry(V<:SharedVolumes &
V.Volume = M.ContainingVolume

&

Dominates(V.SecLevel,M.SecLevel))

&

M.Cylinders.2 > M.Cylinders.1

&

M.Cylinders.1 < #Cylinders(M.ContainingVolume)

&

M.Cylinders.2 <= #Cylinders(M.ContainingVolume)

&

A"C:ProcessLinkEntry(C<:M.CurrentLinks ->

C.Access ~= Empty

&

E"N:NkcpEntry(N<:CurrentNkcps &

N.Process = C.Process

&

E"L:MDLinkEntry(L<:N.Links &

L.MDName = M.MDName

&

L.Access = C.Access)

&

E"A:ACLEntEntry(A<:M.AccessControlList &

E"V:VMEntEntry(V<:N.VMs &

V.VMName = A.User))

&

(Write <: C.Access ->

N.Process = M.SecLevel)))

&

(M.CurrentLinks ~= Empty ->

E"V:SharedVolumeEntry(V<:SharedVolumes &

V.Volume = M.ContainingVolume

&

V.State = Mounted

&

E"S:SharableDriveEntry(S<:SharableDrives &

S.Raddr = V.MountedDevice

&

S.MountedVolume = V.Volume

&

S.State = AttachedToSystem)))

&

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3.3.2 Authorization Process (Formal)

System Development Corporation
TM-5062/101/88

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

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

InvariantsOfCurrentNkcp =

```
A"N1,N2:NkcpEntry(N1<:CurrentNkcp & N2<:CurrentNkcp ->
  (N1.Process = N2.Process -> N1 = N2))
&
A"N:NkcpEntry(N<:CurrentNkcp ->
  A"VM1,VM2:VMEEntry(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:MDLinkEntry(L1<:N.Links & L2<:N.Links ->
    (L1.MDName = L2.MDName -> L1 = L2))
  &
  A"VM:VMEEntry(VM<:N.VMs ->
    E"D:DirectoryEntry(D<:UserDirectory &
      D.UserId = V.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)))
  &
```

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation
TM-6062/101/00

```
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:NonsharableDriveEntry(NS<:NonsharableDrives &
    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:NkcpEntry(N1<:CurrentNkcps & N2<:CurrentNkcps ->
  A"AD1,AD2:AttachedDeviceEntry(
    AD1<:N1.AttachedDevices & AD2<:N2.AttachedDevices ->
    AD1.Raddr ~ AD2.Raddr))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6862/101/88

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))
  &
  (L.State = Attached ->
    L.CyclePosition <: S"(Attached,ReadLinkPassword))
  &
  (L.State = Free ->
    L.CyclePosition <: S"(Disabled,Available,ReEnablePending))
  &
  (L.State <: S"(AttachValidation,Attached) ->
    Dominates(L.MaxSecLevel,L.RequestedSecLevel)
    &
    Dominates(L.RequestedSecLevel,L.MinSecLevel))
  &
  (L.State = Attached ->
    E"N:NkcpEntry(N<:CurrentNkcps &
      N.Process = L.RequestedSecLevel
      &
      E"VM:VMEntry(VM<:N.VMs &
        VM.VMName = L.AttachedVM
        &
        (L.Connection = Logon ->
          VM.Laddr = L.Laddr
          &
          ~VM.Disconnected)
        &
        (L.Connection = Dial ->
          E"U:LineAddress(U<:VM.Users &
            U = L.Laddr))))))
  &
```

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3.3.2 Authorization Process (Formal)

System Development Corporation
TM-6062/101/00

```
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)
```


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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

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)

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6862/181/88

InvariantsOfUserDirectory =

```
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"DD1,DD2:DedicatedDeviceEntry(
    DD1<:D.DedicatedDevices & DD2<:D.DedicatedDevices ->
    (DD1.Raddr = DD2.Raddr -> DD1 = DD2))
  &
  A"DD:DedicatedDeviceEntry(DD<:D.DedicatedDevices ->
    (DeviceType(DD.Raddr) <: S"(Reader,Printer,Punch,TapeDrive) ->
      E"U:URPownedDeviceEntry(U<:URPownedDevices &
        DD.Raddr = U.Raddr
        &
        (DeviceType(DD.Raddr) = Reader ->
          DD.VolSecLevel = nil
          &
          DD.Access = S"(Read))
        &
        (DeviceType(DD.Raddr) <: S"(Printer,Punch)->
          DD.VolSecLevel = nil
          &
          DD.Access = S"(Write))
        &
        (DeviceType(DD.Raddr) = TapeDrive ->
          Dominates(U.MaxSecLevel,DD.VolSecLevel)
          &
          Dominates(DD.VolSecLevel,U.MinSecLevel)
          &
          Dominates(D.MaxSecLevel,DD.VolSecLevel)
          &
          DD.Access ~= Empty)))
    &
    (DeviceType(DD.Raddr) ~<: S"(Reader,Printer,Punch,TapeDrive) ->
      E"NS:NonsharableDriveEntry(NS<:NonsharableDrives &
        NS.Raddr = DD.Raddr
        &
        Dominates(NS.MaxSecLevel,DD.VolSecLevel)
        &
        Dominates(DD.VolSecLevel,NS.MinSecLevel)
        &
        Dominates(D.MaxSecLevel,DD.VolSecLevel)
        &
        DD.Access ~= Empty)))
  &
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```
A"L1,L2:MDLinkEntry(L1<:D.Links & L2<:D.Links ->
  (L1.MDName = L2.MDName -> L1 = L2))
&
A"L:MDLinkEntry(L<:D.Links ->
  E"M:MiniDiskEntry(M<:MiniDisks &
    M.MDName = L.MDName
    &
    E"A:ACLEntry(A<:M.AccessControlList &
      A.User = D.UserId
      &
      L.Access<=<=A.Access)
    &
    Dominates(D.MaxSecLevel,M.SecLevel))
  &
  L.Access ~= Empty)
&
A"AP1,AP2:AccessPasswordEntry(
  AP1<:D.AccessPasswords & AP2<:D.AccessPasswords ->
  (AP1.SecLevel = AP2.SecLevel -> AP1 = AP2))
&
A"AP:AccessPasswordEntry(AP<:D.AccessPasswords ->
  Dominates(D.MaxSecLevel,AP.SecLevel)
  &
  Dominates(AP.SecLevel,D.MinSecLevel)))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

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) ||
S"(L.Laddr,
    L.MaxSecLevel,
    L.MinSecLevel,
/****/ (L.State = Attached
    |
    (L.State = AttachValidation
    &
    L.CyclePosition~<:S"(HookingPeripherals,
        NotifyingNkcp)) =>
        Free
    <> L.State),
/****/ (L.State = Attached
    |
    (L.State = AttachValidation
    &
    L.CyclePosition~<:S"(HookingPeripherals,
        NotifyingNkcp)) =>
        CurrentLineStatus
    <> L.CyclePosition),
/****/ (L.State = Attached
    |
    (L.State = AttachValidation
    &
    L.CyclePosition~<:S"(HookingPeripherals,
        NotifyingNkcp)) =>
        AuthProcess
    <> L.AttachedVM),
/****/ (L.State = AttachValidation
    &
    L.CyclePosition~<:S"(HookingPeripherals,NotifyingNkcp) =>
        true
    <> L.LineDropped),
L.#Retries,
L.#AwaitingHooks,
L.Msg))
&
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6862/181/88

```
(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) ||
    S"((N.Process,
      N.VMs ~ S"(V) ||
      S"((V.VMName,
        V.Laddr,
/****/      (L.Connection = Logon
      &
      L.Laddr = V.Laddr =>
        true
/****/      <> 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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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

LGDL1: Network Process message, LOGON or DIAL request received

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

effect (~(E"L:LineEntry(L<:Lines &
                        L.Laddr = Laddr
                        &
                        L.State = Free
                        &
                        L.CyclePosition = Available))
=> Error <> NoError &
E"L:LineEntry(L<:Lines & L.Laddr = Laddr &
N"Lines = Lines ~ S"(L) ||
(Dominates(L.MaxSecLevel, RequestedSecLevel)
&
Dominates(RequestedSecLevel, L.MinSecLevel) =>
S"((L.Laddr,
    L.MaxSecLevel,
    L.MinSecLevel,
    /****/ AttachValidation,
    /****/ ReadInitialPassword,
    /****/ RequestedSecLevel,
    /****/ UserId,
    /****/ AttemptedCommand,
    /****/ false,
    /****/ 0,
    /****/ 0,
    /****/ nil))
<> S"((L.Laddr,
    L.MaxSecLevel,
    L.MinSecLevel,
    /****/ Free,
    /****/ ReEnablePending,
    /****/ L.RequestedSecLevel,
    /****/ AuthProcess,
    L.Connection,
    L.LineDropped,
    L.#Retries,
    L.#AwaitingHooks,
    L.Msg)))
&
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6862/101/00

```
N"PendingRequests = PendingRequests ||
S" ((NewMsgId,
/****/ (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))))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/181/88

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) ||  
(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,  
      L.RequestedSecLevel,  
      AuthProcess,  
      L.Connection,  
      L.LineDropped,  
      L.#Retries,  
      L.#AwaitingHooks,  
      L.Msg)))  
&
```


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3.3.2 Authorization Process (Formal)

System Development Corporation

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```
N"PendingRequests = PendingRequests ||
S"((NewMagId,
/#####/ (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))))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

LGDL3: Userid, password, and requested security level validations

transform LGDL3(Laddr: LineAddress,
Password: String)

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

effect E"L:LineEntry(L<:Lines & L.Laddr = Laddr &
N"Lines = Lines ~ S"(L) ||
S"((L.Laddr,
L.MaxSecLevel,
L.MinSecLevel,
/*##*/ ((E"D:DirectoryEntry(D<: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 =>
Free
<> L.State),

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3.3.2 Authorization Process (Formal)

System Development Corporation

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```
/****/ (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) =>
            ReadAccessPassword
            <> PerformResourceChecks)
            <> ReEnablePending))
      <> (L.#Retries + 1 = #MaxRetries =>
        ReEnablePending
        <> Retry)),
      L.RequestedSecLevel,
/****/ ((E"D:DirectoryEntry(D<: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(D<:UserDirectory &
      D.UserId = L.AttachedVM
      &
      (L.Connection = Logon ->
        D.LogonPassword = Password)
      &
      (L.Connection = Dial ->
        D.DialPassword = Password))) =>
      L.#Retries + 1
      <> L.#Retries),
      L.#AwaitingHooks,
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

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L.Msg))

&

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```
E"Entry1, Entry2:PendingRequest(
  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)
          <> PendingRequests || S"(Entry2)))
    <> (L.#Retries + 1 = #MaxRetries =>
      PendingRequests || S"(Entry2)
      <> PendingRequests || S"(Entry1))))
&
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-5862/101/88

```
(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) =>
    KernelCalled(SendMessage(
      NetworkProcess)))
  <> KernelCalled(SendMessage(
    NetworkProcess))
  &
  KernelCalled(SendMessage(
    NetworkProcess))))
<> (N"L.#Retries = #MaxRetries =>
  KernelCalled(SendMessage(
    NetworkProcess))
  &
  KernelCalled(SendMessage(
    NetworkProcess))
  <> KernelCalled(SendMessage(
    NetworkProcess))))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

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
&
E"A:AccessPasswordEntry(A<:D.AccessPasswords &
A.SecLevel = L.RequestedSecLevel)))

=> Error <> NoError &
E"D:DirectoryEntry(D<:UserDirectory & D.UserId = L.UserId &
E"A:AccessPasswordEntry(
A<:D.AccessPasswords & A.SecLevel = L.RequestedSecLevel &
N"Lines = Lines ~ S"(L) ||
S"((L.Laddr,

L.MaxSecLevel,
L.MinSecLevel,
/x##x/ (A.Password ~ AccessPassword
&
L.#Retries + 1 = #MaxRetries =>
Free

<> L.State),
/x##x/ (A.Password = AccessPassword =>
PerformResourceChecks
<> (L.#Retries + 1 = #MaxRetries =>
ReEnablePending
<> Retry)),

L.RequestedSecLevel,
/x##x/ (A.Password ~ AccessPassword
&
L.#Retries + 1 = #MaxRetries =>

AuthProcess
<> L.AttachedVM),
L.Connection,
L.LineDropped,
/x##x/ (A.Password ~ AccessPassword =>

L.#Retries + 1
<> L.#Retries),
L.#AwaitingHooks,
L.Msg))

&

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```
(A.AccessPassword ~= Password =>
N"PendingRequests = PendingRequests ||
S"((NewMsgId,
/****/ (L.#Retries + 1 = #MaxRetries =>
      ClearLine
      <> WriteAndReadLine),
/****/ Undefined,
      S"((NetworkProcess,
          nil,
          NoResponse))))
<> N"PendingRequests = PendingRequests)
&
(A.Password ~= AccessPassword =>
  KernelCalled(SendMessage(OpProcess))
  &
  (L.#Retries + 1 = #MaxRetries =>
    KernelCalled(SendMessage(
      NetworkProcess))
    &
    KernelCalled(SendMessage(
      NetworkProcess))
    <> KernelCalled(SendMessage(
      NetworkProcess))))))
```


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3.3.2 Authorization Process (Formal)

System Development Corporation
TM-5862/101/00

LGDL5: Perform resource checks

transform LGDL5(Laddr: LineAddress)

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

effect E"L:LineEntry(L<:Lines & L.Laddr = Laddr &
(~(E"D:DirectoryEntry(D<:UserDirectory &
D.UserId = L.AttachedVM)
&
~ShuttingDown)
=> Error <> NoError &
E"D:DirectoryEntry(D<:UserDirectory & D.UserId = L.AttachedVM &
/* not specified */ true)))

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/181/00

LGDL6: Attach Dedicated Devices

transform LGDL6(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"N:NkcpEntry(N<:CurrentNkcps & N.Process = L.AttachedProcess &
 E"D:DirectoryEntry(D<:UserDirectory & D.UserId = L.AttachedVM &
/* not specified */ true)))

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

LGDL7: Perform Links at Logon

transform LGDL7(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<:CurrentNkcp &
        N.Process = L.AttachedProcess)
    &
    E"D:DirectoryEntry(D<:UserDirectory &
        D.UserId = L.AttachedVM))
=> Error <> NoError &
    E"N:NkcpEntry(N<:CurrentNkcp & N.Process = L.AttachedProcess &
    E"D:DirectoryEntry(D<:UserDirectory & D.UserId = L.AttachedVM &
/* not specified */ true)))
```

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 3.3.2 Authorization Process (Formal) TM-6062/101/00

LGDL8: Response to message to NKCP re new VM

```

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

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

effect E"L:LineEntry(L<:Lines & L.Laddr = Laddr &
                    (~L.AttachedVM = VM
                     &
                     L.State = AttachValidation
                     &
                     L.CyclePosition = NotifyingNkcp)
=> Error <> NoError &
    N"Lines = Lines ~ S"(L) ||
    S"((L.Laddr,
        L.MaxSecLevel,
        L.MinSecLevel,
/*###*/ (Responded(Process) =>
        Attached
        <> (A"N:NkcpEntry(N<:CurrentNkcp &
                        N.Process ~ Process)
        &
        L.LineDropped =>
        Free
        <> L.State)),
/*###*/ (Responded(Process) =>
        Attached
        <> (E"N:NkcpEntry(N<:CurrentNkcp &
                        N.Process = Process)
        |
        L.LineDropped =>
        L.CyclePosition
        <> PerformResourceChecks)),
        L.RequestedSecLevel,
        L.AttachedVM,
        L.Connection,
        L.LineDropped,
        L.#Retries,
        L.#AwaitingHooks,
        L.Msg))
&

```

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3.3.2 Authorization Process (Formal)

System Development Corporation

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```
(Responded(Process) =>
  KernelCalled(SendMessage(NetworkProcess))
  <> (E"N:NkcpEntry(N<:CurrentNkcp &
      N.Process = Process) =>
      KernelCalled(SendMessage(Process))
      <> (L.LineDropped ->
          KernelCalled(SendMessage(
              NetworkProcess))))))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6862/101/00

NKCP1: Disconnect

```
transform NKCP1(Process: ProcessName,
                VM: VirtualMachineName,
                Laddr: LineAddress
                LineAction: String)

effect  (~(E"N:NkcpEntry(N<:CurrentNkcps &
                        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<:CurrentNkcps & N.Process = Process &
        N"Lines = Lines ~ S"(L) ||
        S"((L.Laddr,
            L.MaxSecLevel,
            L.MinSecLevel,
/****/      (E"V:VMEEntry(V<:N.VMs &
                        V.VMName = VM
                        &
                        V.Laddr = Laddr
                        &
                        ~V.Disconnected) =>
                        Free
                        <> L.State),
/****/      (E"V:VMEEntry(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))
        &
```

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3.3.2 Authorization Process (Formal)

System Development Corporation
TM-6062/101/00

```
N"#Users =
  (E"V:VMEntry(V<:N.VMs &
    V.VMName = VM
    &
    V.Laddr = Laddr
    &
    ~V.Disconnected) =>
    #Users - 1
    <> #Users)
&
N"PendingRequests =
  (E"V:VMEntry(V<:N.VMs &
    V.VMName = VM
    &
    V.Laddr = Laddr
    &
    ~V.Disconnected) =>
    PendingRequests ||
    S"((NewMagId,
      (LineAction = 'hold' =>
        ReDirectLine
        ClearLine),
      <>
        Undefined,
        S"((NetworkProcess,
          nil,
          NoResponse))))
    <> PendingRequests)
&
(E"V:VMEntry(V<:N.VMs &
  V.VMName = VM
  &
  V.Laddr = Laddr
  &
  ~V.Disconnected) ->
  E"V:VMEntry(V<:N.VMs & V.VMName = VM &
    V.Laddr = Laddr
    &
    (~V.Disconnected)
    &
    N"CurrentNkcps = CurrentNkcps ~ S"(N) ||
    S"((N.Process,
      N.VMs ~ S"(V) ||
      S"((V.VMName,
        V.Laddr,
        true,
        V.Users)),
      N.AttachedDevices,
      N.Links))))
&
KernelCalled(SendMessage(NetworkProcess))))
```

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation
TM-6062/101/00

NKCP2: Logoff

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

```
effect (~ (E"N:NkcpEntry(N<:CurrentNkcp &
    N.Process = Process
    &
    E"V:VMEntry(V<:N.VMs &
    V.VMName = VM)))
=> Error <> NoError &
E"N:NkcpEntry(N<:CurrentNkcp & N.Process = Process &
E"V:VMEntry(V<:N.VMs & V.VMName = VM &
N"#Users =
    (DestroyedVM =>
        #Users - C"V.Users - 1
    <> #Users)
&
N"#VMs =
    (DestroyedVM =>
        #VMs - 1
    <> #VMs)
&
N"CurrentNkcp =
    (DestroyedVM =>
        CurrentNkcp ~ S"(N) ||
        S"((N.Process,
            N.VMs ~ S"(V),
            N.AttachedDevices,
            N.Links))
    <> CurrentNkcp)
&
N"PendingRequests =
    (DestroyedVM
    &
    ~ V.Disconnected =>
        PendingRequests || S"P:PendingRequest(
            E"U:LineAddress(U<:V.Users &
            P=(NewMsgId,
                ClearLine(U),
                Undefined,
                S"((NetworkProcess,
                    nil,
                    NoResponse))))))
||
```


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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```

                                S"((NewMsgId,
                                (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.MaxSecLevel,
        Free,
        ReEnablePending,
        L.RequestedSecLevel,
        L.AttachedVM,
        L.Connection,
        L.LineDropped,
        L.#Retries,
        L.#AwaitingHooks,
        L.Msg))))
&
KernelCalled(DestroyVM(V.VMName))
&
(DestroyedVM =>
  (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)

System Development Corporation

TM-6062/101/00

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.IplDefined = true  
    &  
    & A"A:AccessPasswordEntry(A<:D.AccessPasswords &  
        A.SecLevel = RequestedSecLevel ->  
        A.Password = AccessPassword))  
    &  
    & ~ ShuttingDown  
    &  
    & #VMs < #MaxVMs)  
=> Error <> NoError &  
/* not specified */ true)
```

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6862/101/00

UR2 and OP2: Map user id

transform UR2(UserId: VirtualMachineName,
Requester: ProcessName)

refcond Requester <: S"(OpProcess, URProcess)

effect KernelCalled(SendMessage(Requester))

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6862/181/88

OP4b: Detach of shared device (by operator)

transform OP4b(Raddr: DeviceAddress)

refcond E"S:SharableDriveEntry(S<:SharableDrives &
S.Raddr = Raddr)

```
effect E"S:SharableDriveEntry(  
  S<:SharableDrives & S.Raddr = Raddr &  
  N"SharableDrives = SharableDrives ~ S"(S) ||  
  S"((S.Raddr,  
    /****/ (S.State = AttachedToSystem  
    &  
    A"M:MiniDiskEntry(M<:MiniDisks &  
    M.ContainingVolume = S.MountedVolume ->  
    M.CurrentLinks = Empty)  
    &  
    DeviceIsReleasable  
    &  
    DeviceReleased ->  
    Available  
    <> S.State),  
    S.SecLevel,  
    S.MountedVolume))  
    &  
    (S.State = AttachedToSystem  
    &  
    A"M:MiniDiskEntry(M<:MiniDisks &  
    M.ContainingVolume = S.MountedVolume ->  
    M.CurrentLinks = Empty)  
    &  
    DeviceIsReleasable  
    &  
    DeviceReleased ->  
    E"V:SharedVolumeEntry(V<:SharedVolumes &  
    V.MountedDevice = S.MountedVolume  
    &  
    N"SharedVolumes = SharedVolumes ~ S"(V) ||  
    S"((V.Volume,  
    V.SecLevel,  
    nil,  
    NotMounted))))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```
&
KernelCalled(SendMessage(OpProcess))
&
(S.State = AttachedToSystem ->
  (A*M:MiniDiskEntry(M<:MiniDisks &
    M.ContainingVolume = S.MountedVolume ->
      M.CurrentLinks = Empty) ->
    KernelCalled(IsDeviceReleasable)
    &
      (DeviceIsReleasable ->
        KernelCalled(ReleaseDevice))))))
```

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6862/101/88

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) ||  
  S"((NS.Raddr,  
    NS.MaxSecLevel,  
    NS.MinSecLevel,  
    /*##*/ (NS.State = AttachedToUser =>  
      DetachPending  
      <> NS.State),  
    NS.AttachedProcess,  
    NS.Access))  
  &  
  N"PendingRequests =  
    (NS.State = AttachedToUser =>  
      PendingRequests ||  
      S"((NewMsgId,  
        RelinquishDevice,  
        DETACH+RADDR,  
        S"((NetworkProcess,  
          nil,  
          NoResponse))))  
      <> PendingRequests)  
  &  
  (NS.State = AttachedToUser =>  
    KernelCall(SendMessage(NS.AttachedProcess))  
    <> (NS.State <: S"(OffLine, Available) ->  
      KernelCalled(SendMessage(OpProcess))))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6862/181/00

OP5a: Vary (both online and offline) of shared device

transform OP5a(Raddr: DeviceAddress,
Parameter: String)

refcond E"S:SharableDriveEntry(S<:SharableDrives &
S.Raddr = Raddr)

```
effect (Parameter ~<: S"('online', 'offline')
=> Error <> NoError &
    E"S:SharableDriveEntry(
        S<:SharableDrives & S.Raddr = Raddr &
        N"SharableDrives = SharableDrives ~ S"(S) ||
        S"((S.Raddr,
/###/ (Parameter = 'online' =>
        Available
        <> OffLine),
        S.SecLevel,
        S.MountedVolume))
&
    KernelCalled(SendMessage(OpProcess)))
```

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation
TM-6062/101/00

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)))
```


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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

OP6a: QUERY, with parameters:

DASD
LINES
GRAF
ALL
NAMES
USERS with no further parameter

transform OP6a(Command:CommandName)

refcond Command<:Cat6a

effect KernelCalled(SendMessage(OpProcess))

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

OP6b: QUERY, with parameters:

raddr

SYSTEM raddr

transform OP6b(Command: CommandName,
Raddr: DeviceAddress)

refcond Command<:Cat6b

effect (~ (E"S:SharableDriveEntry(S<:SharableDrives &
S.Raddr = Raddr)
|
E"NS:NonSharableDriveEntry(NS<:NonSharableDrives &
NS.Raddr = Raddr))
=> Error <> NoError &
KernelCalled(SendMessage(OpProcess)))

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation
TM-6862/101/00

OP6c: QUERY, with parameters:
USERS userid
userid

transform OP6c(Command: CommandName,
 UserId: VirtualMachineName)

refcond Command<:Cat6c

effect KernelCalled(SendMessage(OpProcess))

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

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,
 OpRequest,
 LOCATE+RADDR,
/###/ S"((NS.AttachedProcess,
 nil,
 NoResponse))))
 <> PendingRequests)
 &
 (NS.State = AttachedToUser =>
 KernelCalled(SendMessage(NS.AttachedProcess))
 <> KernelCalled(SendMessage(OpProcess))))

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/88

OP8: Shutdown

transform OP8

effect N"ShuttingDown = true

OP3: Attach (nonsharable disk drive) Device

```
transform OP3(Raddr: DeviceAddress,  
              Process: ProcessName,  
              VolSecLevel: ProcessName,  
              Access: set of AccessModes)  
  
refcond E"NS:NonsharableDriveEntry(NS<:NonsharableDrives &  
    * NS.Raddr = Raddr)  
  
effect E"NS:NonsharableDriveEntry(  
    NS<:NonsharableDrives & NS.Raddr = Raddr &  
    (~E"N:NkcpEntry(N<:CurrentNkcp &  
        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 &
```

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```

E"N:NkcpEntry(N:CurrentNkcp & N.Process = Process &
N"NonsharableDrives = NonsharableDrives ~ 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"CurrentNkcp = CurrentNkcp ~ 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))))))

```

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6862/181/88

UR1: URProcess request: need Nkcp

transform UR1 (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:NkcpEntry(N<:CurrentNkcps ->
            N.Process ~ RequestedSecLevel)
            &
            Dominates(D.MaxSecLevel, RequestedSecLevel)
            &
            Dominates(RequestedSecLevel, D.MinSecLevel)
            &
            #Nkcps < #MaxNkcps
            &
            CreatedProcess =>
                #Nkcps + 1
            <> #Nkcps)
        &
        N"CurrentNkcps =
            (A"N:NkcpEntry(N<:CurrentNkcps ->
                N.Process ~ RequestedSecLevel)
                &
                Dominates(D.MaxSecLevel, RequestedSecLevel)
                &
                Dominates(RequestedSecLevel, D.MinSecLevel)
                &
                #Nkcps < #MaxNkcps
                &
                CreatedProcess =>
                    CurrentNkcps ||
                    S"((RequestedSecLevel,
                        Empty,
                        Empty,
                        Empty))
                <> CurrentNkcps)
        &
```


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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```
(E"N:NkcpEntry(N<:CurrentNkcps &
  N.Process = RequestedSecLevel) =>
  KernelCalled(SendMessage(URProcess))
<> (Dominates(D.MaxSecLevel, RequestedSecLevel)
  &
    Dominates(RequestedSecLevel, D.MinSecLevel)
  &
    #Nkcps < #MaxNkcps =>
      KernelCalled(CreateProcess)
    &
      (CreatedProcess =>
        KernelCalled(SendMessage(
          URProcess))
        &
          KernelCalled(SendMessage(
            OpProcess))
        &
          KernelCalled(SendMessage(
            URProcess))
        <> KernelCalled(SendMessage(
          URProcess)))
    <> KernelCalled(SendMessage(URProcess))))))
```

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

UR3a: URProcess 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) ||  
S"((L.Laddr,  
   L.MaxSecLevel,  
   L.MinSecLevel,  
   L.State,  
/s###/ (L.#AwaitingHooks - 1 = 0 =>  
        NotifyingNkcp,  
        <> L.CyclePosition),  
   L.RequestedSecLevel,  
   L.AttachedVM,  
   L.Connection,  
   L.LineDropped,  
   L.#Retries,  
/s###/ L.#AwaitingHooks - 1,  
/s###/ Concat(L.Msg, Avail(Raddr))))  
&
```

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation
TM-6062/101/00

```
N"PendingRequests =  
  (L.#AwaitingHooks - 1 = 0 =>  
    PendingRequests ||  
    S"((NewMsgId,  
      NewVM,  
      Undefined,  
      S"((Process,  
        nil,  
        NoResponse))))  
    <> PendingRequests)  
&  
(L.#AwaitingHooks - 1 = 0 ->  
  (~L.LineDropped ->  
    KernelCalled(SendMessage(  
      NetworkProcess)))  
&  
  KernelCalled(SendMessage(Process))))
```

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

UR3b: URProcess response to device attachment request (attach failed)

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

```
effect  (~("A:URPOwnedDeviceEntry(A<:URPOwnedDevices &
        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,
    /sHsH/ (L.#AwaitingHooks - 1 = 0 =>
            NotifyingNkcp
            <> L.CyclePosition),
    L.RequestedSecLevel,
    L.AttachedVM,
    L.Connection,
    L.LineDropped,
    L.#Retries,
    /sHsH/ L.#AwaitingHooks - 1,
    /sHsH/ Concat(L.Msg,Unavail(Raddr))))
&
```

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```
N"PendingRequests =
  (L.#AwaitingHooks - 1 = 0 ->
    PendingRequests ||
      S"((NewMsgId,
        NewVM,
        Undefined,
        S"((Process,
          nil,
          NoResponse))))
    <> PendingRequests)
&
(L.#AwaitingHooks = 1 - 0 ->
  (~L.LineDropped ->
    KernelCalled(SendMessage(
      NetworkProcess)))
  &
  KernelCalled(SendMessage(Process))))
```

21 May 1978

3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6962/181/00

NKCP3: Drop User

transform NKCP3 (Process: ProcessName,
VM: VirtualMachineName,
Laddr: LineAddress)

```
effect (~ (E "N: NkcpEntry (N<: CurrentNkcp &
      N.Process = Process
      &
      E "V: VEntry (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) ||
S" ((L.Laddr,
L.MaxSecLevel,
L.MinSecLevel,
/#####/ Free,
/#####/ ReEnablePending,
L.RequestedSecLevel,
L.AttachedVM,
L.Connection,
L.LineDropped,
L.#Retries,
L.#AwaitingHooks,
L.Msg))
&
```

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3.3.2 Authorization Process (Formal)

System Development Corporation
TM-6062/101/00

```
E"N:NkcpEntry(N<:CurrentNkcp & N.Process = Process &
E"V:VMEntry(V<:N.VMs & V.VMName = VM &
N"CurrentNkcp = CurrentNkcp ~ S"(N) ||
S"(N.Process,
  N.VMs ~ S"(V) ||
  S"((V.VMName,
    V.Laddr,
    V.Disconnected,
    V.Users ~ S"(Laddr))),
  N.AttachedDevices,
  N.Links)))
&
N"PendingRequests = PendingRequests ||
S"((NewMsgId,
  ClearLine,
  Undefined,
  S"((NetworkProcess,
    nil,
    NoResponse))))
&
KernelCalled(SendMessage(NetworkProcess))
&
KernelCalled(SendMessage(OpProcess))
&
KernelCalled(SendMessage(AcntProcess)))
```

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3.3.2 Authorization Process (Formal) System Development Corporation
TM-6062/101/00

NTWK3: Link password received

transform NTWK3(Process: ProcessName,
Password: String,
Requester: VirtualMachineName,
Laddr: LineAddress,
User: VirtualMachineName,
MiniDisk: MiniDiskName,
RequestedAccess: LinkAccess)

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

effect (~E"N:NkcpEntry(N<:CurrentNkcp &
N.Process = Process))
=> Error <=> NoError &
E"N:NkcpEntry(N<:CurrentNkcp & N.Process = Process &
E"D:DirectoryEntry(D<:UserDirectory & D.UserId = User &
E"L:LineEntry(L<:Lines & L.Laddr = Laddr &
N"Lines = Lines ~ S"(L))
S"((L.Laddr,
L.MaxSecLevel,
L.MinSecLevel,
L.State,
Attached,
L.RequestedSecLevel,
L.AttachedVM,
L.Connection,
L.LineDropped,
L.#Retries,
L.#AwaitingHooks,
L.Msg))

&
ID.LinkPassword = Password ->
E"M:MiniDiskEntry(M<:MiniDisks &
M.MDName = MiniDisk
&
E"V:SharedVolumeEntry(V<:SharedVolumes &
V.Volume = M.ContainingVolume
&
V.State = Mounted ->
E"S:SharableDriveEntry(S<:SharableDrives &
S.Raddr = V.MountedDevice
&
(S.State = AttachedToSystem ->
E"A:ACLEntry(A<:M.AccessControlList &
A.User = Requester
&

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```
(RequestedAccess = R =>
  ("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))
    <> Link(N.Process,M.MDName,S"(Read)))
  <> /* choices: Link(N.Process,M.MDName,S"(Read))
      NoLink(NoWritePermission) */
  NoLink(NoWritePermission))

<> RequestedAccess = M =>
  (Write <: A.Access =>
    ("C:ProcessLinkEntry(C<:M.CurrentLinks ->
      Write ~<: C.Access) =>
        Link(N.Process,M.MDName,S"(Write))
      <> NoLink(PreviousWriteLink))
  <> NoLink(NoWritePermission))

<> RequestedAccess = MR =>
  (Write <: A.Access =>
    ("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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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```
transform Link(Process: ProcessName,
               MiniDisk: MiniDiskName,
               Access:set of AccessModes)

effect  E"N:NkcpEntry(N<:CurrentNkcp & N.Process = Process &
    E"M:MiniDiskEntry(M<:MiniDisks & M.MDName = MiniDisk &
    (E"MPL:ProcessLinkEntry(
        MPL<:M.CurrentLinks & MPL.Process = N.Process) =>
    E"MPL:ProcessLinkEntry(
        MPL<:M.CurrentLinks & MPL.Process = N.Process &
    E"NML: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"((MDL.Process,
                Access)),
            M.AccessControlList))
        <> N"CurrentNkcp = CurrentNkcp
        &
        N"MiniDisks = MiniDisks)))
    <> KernelCalled(GrantAccess)
    &
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```
(GrantedAccess =>
  N"CurrentNkcps = CurrentNkcps ~ S"(N) ||
  S"((N.Process,
    N.VMs,
    N.AttachedDevices,
    N.Links ||
    S"((M.MDName,
      Access))))
  &
  N"MiniDisks = MiniDisks ~ S"(M) ||
  S"((M.MDName,
    M.ContainingVolume,
    M.Cylinders,
    M.SecLevel,
    M.CurrentLinks ||
    S"((N.Process,
      Access)),
    M.AccessControlList))
  <> N"CurrentNkcps = CurrentNkcps
  &
  N"MiniDisks = MiniDisks)))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation
TM-6862/101/00

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:VMEEntry(E<:N.VMs &  
          E.VMName = Requester))  
      &  
      E"L:LineEntry(L<:Lines &  
        L.Laddr = Laddr  
        &  
        L.State = Attached  
        &  
        L.CyclePosition = Attached  
        &  
        L.RequestedSecLevel = Process  
        &  
        L.AttachedVM = Requester)  
      &  
      E"D:DirectoryEntry(D<:UserDirectory &  
        D.UserId = User  
        &  
        E"K:MDLinkEntry(K<:D.Links &  
          K.MDName = MiniDisk))  
      &  
      E"M:MiniDiskEntry(M<:MiniDisks &  
        M.MDName = MiniDisk  
        &  
        E"A:ACLEEntry(A<:M.AccessControlList &  
          A.User = Requester  
          &  
          Dominates(Process, M.SecLevel)  
          &  
          (Write<:RequestedAccess ->  
            Process = M.SecLevel)))  
      &
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-S062/101/00

```

                                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) ||
S"((L.Laddr,
    L.MaxSecLevel,
    L.MinSecLevel,
    L.State,
    L.CyclePosition,
    L.RequestedSecLevel,
    L.AttachedVM,
    L.Connection,
    L.LineDropped,
    L.#Retries,
    L.#AwaitingHooks,
    L.Msg)))
                                &
                                N"PendingRequests = PendingRequests ||
                                S"((NewMsgId,
                                WriteAndReadLine,
                                Undefined,
                                S"((NetworkProcess,
                                nil,
                                NoResponse))))
<> N"Lines = Lines
                                &
                                N"PendingRequests = PendingRequests
                                &
                                KernelCalled(SendMessage(Process)))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

NKCP5, NKCP6: Detach nonsharable 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:NonsharableDriveEntry(NS<:NonsharableDrives &  
      NS.Raddr = Raddr  
      &  
      NS.AttachedProcess = Process))  
=> Error <> NoError &  
  E"NS:NonsharableDriveEntry, N:NkcpEntry(  
    NS<:NonsharableDrives & NS.Raddr = Raddr &  
    N<:CurrentNkcps & N.Process = Process &  
    N"NonsharableDrives = NonsharableDrives ~ S"(NS) ||  
    S"((NS.Raddr,  
      NS.MaxSecLevel,  
      NS.MinSecLevel,  
      (DeviceReleased =>  
        Available  
        <> NS.State),  
      NS.AttachedProcess,  
      NS.Access))  
    &  
    N"CurrentNkcps = CurrentNkcps ~ S"(N) ||  
    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)

System Development Corporation

TM-6062/101/00

```
&  
KernelCalled(ReleaseDevice(NS.Raddr))  
&  
KernelCalled(SendMessage(OpProcess))  
&  
(DeviceReleased =>  
    KernelCalled(SendMessage(AcntProcess'))  
    <> KernelCalled(SendMessage(NS.AttachedProcess))))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

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))
```


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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6862/101/88

KERN1: message from Kernel, re shared device availability

```
transform KERN1 (Raddr: DeviceAddress,  
                Volume: VolumeId,  
                CurrentStatus: SharableDriveStatus)
```

```
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,VnewSecLevel) =>  
                        N"SharableDrives = SharableDrives ~ S"(S) ||  
                        S"((S.Raddr,  
                            S.State,  
                            S.SecLevel,  
                            Vnew.Volume))  
                    &  
                    N"SharedVolumes = SharedVolumes  
                    ~ S"(Vold,Vnew)  
                    ||  
                    S"((Vold.Volume,  
                        Vold.SecLevel,  
                        nil,  
                        NotMounted))  
                    ||  
                    S"((Vnew.Volume,  
                        Vnew.SecLevel,  
                        S.Raddr,  
                        Mounted))  
                    &
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```
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) ||
S"((S.Raddr,
CurrentStatus,
S.SecLevel,
nil))
&
N"SharedVolumes = SharedVolumes ~ S"(V) ||
S"((V.Volume,
V.SecLevel,
nil,
NotMounted)))
<> (CurrentStatus = AttachedToSystem =>
E"V:SharedVolumeEntry(V<:SharedVolumes &
V.Volume = Volume
&
(Dominates(S.SecLevel,V.SecLevel) =>
N"SharableDrives = SharableDrives ~ S"(S) ||
S"((S.Raddr,
AttachedToSystem,
S.SecLevel,
V.Volume))
&
N"SharedVolumes = SharedVolumes ~ S"(V) ||
S"((V.Volume,
V.SecLevel,
S.Raddr,
Mounted))
&
KernelCalled(DriveMatchesVolume)
<> N"SharableDrives = SharableDrives
&
N"SharedVolumes = SharedVolumes
&
KernelCalled(DriveDoesNotMatchVolume)))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```
<> N"SharableDrives = SharableDrives ~ S"(S) II
    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)<:S" (VARY<-ONLINE, VARY<-OFFLINE) =>
            (E"NS: NonsharableDriveEntry(NS<:NonsharableDrives &
              NS.Raddr = Raddr(Text)) =>
              OP5b
              <> E"S: SharableDriveEntry(S<:SharableDrives &
                S.Raddr = Raddr(Text)) =>
                OP5a
                <> Error)
            <> MsgName(Text)<:Cat6a =>
              OPGa
            <> MsgName(Text)<:Cat6b
              OPGb
            <> MsgName(Text)<:Cat6c =>
              OP6c
            <> MsgName(Text) = LOCATE-RADDR =>
              OP7a
            <> MsgName(Text) = SHUTDOWN =>
              OP8
            <> MsgName(Text) = MapUserId =>
              OP2
            <> Error))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```
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 = Attach =>  
        (MsgName(Text) = Attached =>  
            UR3a  
            <> MsgName(Text) <: S"(AttachFailed, DeviceNotAvailable) =>  
                UR3b  
            <> Error)  
        <> Error))  
    <> (MsgName(Text) = NeedNkcp =>  
        UR1  
        <> MsgName(Text) = MapUserId =>  
            UR2  
        <> Error))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation
TM-6862/101/88

```
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 =  
    PerformResourceChecks ->  
    (LGDL5  
    &  
    (TEMP"L.CyclePosition =  
    AttachDevices ->  
    (LGDL6  
    &  
    LGDL7))))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation
TM-6062/101/00

```
<> L.CyclePosition =  
    ReadAccessPassword =>  
    LGDL4  
    &  
    (TEMP"L.CyclePosition =  
        PerformResourceChecks ->  
        (LGDL5  
            &  
            (TEMP"L.CyclePosition =  
                AttachDevices ->  
                (LGDL6  
                    &  
                    LGDL7))))  
    <> Error)  
    <> Error))  
    <> Error)  
    <> MsgName(Text) = LineStatus =>  
        NTWK1  
    <> Error)  
    <> Error))  
    <> (MsgName(Text) = LineStatus =>  
        NTWK1  
    <> MsgName(Text) = LineInfo =>  
        LGDL1  
    <> Error))
```

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3.3.2 Authorization Process (Formal)

System Development Corporation

TM-6062/101/00

```
transform MsgNkcp(MsgId: MessageId,  
                  Text: String,  
                  Source: ProcessName)
```

```
refcond Source ~<: TrustedProcesses|NetworkProcess
```

```
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<: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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3.3.2 Authorization Process (Formal)

System Development Corporation
TM-6062/101/00

```
transform AuthDriver (InterruptType: ?,
                      InterruptSubType: ?,
                      MsgId: MessageId,
                      Text: String,
                      Source: ProcessName)

effect (InterruptType = ExternalInterrupt =>
       (InterruptSubType = Message =>
        MessageReceived
        &
        (Source = OpProcess =>
         MsgOp(MsgId, Text, Source)
        <> Source = URProcess =>
         MsgUR(MsgId, Text, Source)
        <> Source = NetworkProcess =>
         MsgNet(MsgId, Text, Source)
        <> Source ~<: TrustedProcesses | NetworkProcess =>
         MsgNkcp(MsgId, Text, Source)
        <> Error)
       <> Error)
&
KernelCalled(ReceiveInterrupts)
&
KernelCalled(ReleaseCPU)
end AuthProcess
```

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System Development Corporation

3.4.1 Accounting Process (Informal)

TM-6862/101/00

3.4.1: Accounting Process Informal Description

This section contains the informal description of the Accounting Process of KVM/370.

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 π -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 "OP1", the "effect" section says nothing about actually saving the old data base, presumably as a spool file intended for the card punch.

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3.4.1 Accounting Process (Informal)

System Development Corporation
TM-6062/101/00

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.

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3.4.1 Accounting Process (Informal)

System Development Corporation

TM-6062/101/00

Communication between the Operator and the Accounting Process

There are two operator commands which affect the Accounting Process:

- ACNT; and
- 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.

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3.4.2 Accounting Process (Formal)

System Development Corporation
TM-6062/101/00

3.4.2: Accounting Process
Formal Specification

```
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 */

  constant
    MsgName(String): MessageLabels,
    User(String): VirtualMachineName,
    NewPosting(String): String
```

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3.4.2 Accounting Process (Formal)

System Development Corporation
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```
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
A"A1,A2:AccountingRecord (A1<:Accounting
&
A2<:Accounting ->
(A1.User = A2.User -> A1 = A2))
```

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3.4.2 Accounting Process (Formal)

System Development Corporation
TM-6 62/101/00

Subdriver of AcntProcess,
handling messages from AuthProcess

transform MsgAuth(MsgId: MessageId,
Text: String,
Source: ProcessName)

refcond Source = AuthProcess

effect (MsgName(Text) <: S" (SystemResourceUse, DeviceUse) =>
AUTH1 (User (Text), NewPosting (Text))
<> Error)

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TM-6062/101/00

handling messages from OpProcess

```
Text: String,
Source: ProcessName)
```

OP 1

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3.4.2 Accounting Process (Formal)

System Development Corporation
TM-6062/101/00

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
&
NewPosting<:A.Postings))

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3.4.2 Accounting Process (Formal)

System Development Corporation
TM-6062/101/00

OP1: Operator command to re-initialize the accounting data base
transform OP1

effect N"Accounting = Empty
&
KernelCalled(SendMessage(OpProcess))

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3.4.2 Accounting Process (Formal)

System Development Corporation
TM-6062/101/00

```
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)
    <> Error)
end AcntProcess
```

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3.5.1 Updater Process (Informal)

System Development Corporation
TM-6862/101/00

3.5.1: Updater Process Informal Description

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.

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3.5.1 Updater Process (Informal)

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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 (ECMODE, 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, 'e', '[', '#', '"']). 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)

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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

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3.5.1 Updater Process (Informal)

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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 SSO.

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.

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3.5.1 Updater Process (Informal)

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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 KVM'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 Initiator requesting permission to do so. The Initiator will reply OK if the area is not currently in use, otherwise NO. In either case, the Initiator 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 Initiator to use the new copy for all future requests. Upon receipt of that message, the Initiator 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.

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-6062/101/00

3.5.2: Updater Process
Formal Specification

```
module UpdaterProcess
  type
    Char,
    String = list of Char,

    DeviceAddress,
    LineAddress,
    VolumeId,
    ProcessName,
    VirtualMachineName,
    DeviceTypes = (Reader, Printer, Punch, TapeDrive, NonsharableDisk)

  constant
    Dominates(ProcessName, ProcessName): boolean,
    DeviceType(DeviceAddress): DeviceTypes,
    #MaxCylinders: integer,
    #Cylinders(VolumeId): integer
```

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-6062/101/00

```
type
AccessModes = (Read, Write),

PossibleEntries = (Paging, Spooling, MiniDisk, Unknown, System),

CylInt = 1..integer(1 <= 1 & 1 <= #MaxCylinders),

DirectoryEntry = structure of (
    UserId = VirtualMachineName,
    LogonPassword = String,
    DialPassword = String,
    LinkPassword = String,
    MaxSecLevel = ProcessName,
    MinSecLevel = ProcessName,
    DedicatedDevices = set of DedicatedDeviceEntry,
    Links = set of MDLinkEntry,
    IplDefined = boolean,
    AccessPasswords = set of AccessPasswordEntry),

LineEntry = structure of (
    Laddr = LineAddress,
    MinSecLevel = ProcessName,
    MaxSecLevel = ProcessName),

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

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

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

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

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

SharableDriveEntry = structure of (
    Raddr = DeviceAddress,
    SecLevel = ProcessName),
```

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3.5.2 Updater Process (Formal)

System Development Corporation
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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 (
MDName = MiniDiskName,
ContainingVolume = VolumeId,
Cylinders = CylInt >< CylInt,
SecLevel = ProcessName,
AccessControlList = set of ACLEntry),

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

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-S062/101/00

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

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-6062/101/00

transform Updater Process

effect DistinctDeviceAddresses
 &
 LegalUserDirectory
 &
 LegalLines
 &
 LegalMiniDisks
 &
 LegalSharedVolumes
 &
 LegalSharableDrives
 &
 LegalNonSharableDrives
 &
 LegalURPOwnedDevices

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-6062/101/00

DistinctDeviceAddresses =

```
A"U:URPOwnedDeviceEntry(U<:URPOwnedDevices ->
  (A"NS:NonsharableDriveEntry(NS<:NonsharableDrives ->
    (U.Raddr ~= NS.Raddr))
  &
  A"S:SharableDriveEntry(S<:SharableDrives ->
    (U.Raddr ~= S.Raddr))))
&
A"NS:NonsharableDriveEntry(NS<:NonsharableDrives ->
  A"S:SharableDriveEntry(S<:SharableDrives ->
    NS.Raddr ~= S.Raddr))
```

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-6062/101/00

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)))
```

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-6062/101/00

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(D<:URPOwnedDevices &
(D.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(D.MaxSecLevel,E.VolSecLevel)
&
Dominates(E.VolSecLevel,D.MinSecLevel)
&
Dominates(U.MaxSecLevel,E.VolSecLevel)
&
~Empty(E.Access)))
))
xor
E"D:NonsharableDriveEntry(D<:NonsharableDrives &
(D.Raddr = E.Raddr
&
Dominates(D.MaxSecLevel,E.VolSecLevel)
&
Dominates(E.VolSecLevel,D.MinSecLevel)
&
Dominates(U.MaxSecLevel,E.VolSecLevel)
&
~Empty(E.Access)))
&
```

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3.5.2 Updater Process (Formal)

System Development Corporation
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```
A"L1,L2:MDLinkEntry(L1<:U.Links
&
L2<:U.Links ->
(L1.MDName = L2.MDName -> L1 = L2))
&
A"L:MDLinkEntry(L<:U.Links ->
E"M:MiniDiskEntry(M<:MiniDisks &
(M.MDName = L.MDName
&
E"A:ACLEntry(A<:M.AccessControlList &
(A.User = U.UserId
&
A"AM:AccessModes(AM<:L.Access ->
AM<:A.Access)))
&
Dominates(U.MaxSecLevel,M.SecLevel)))
&
~Empty(L.Access))
```

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-6062/101/00

LegalAccessPasswords(U:DirectoryEntry) =

```
A"A1,A2:AccessPasswordEntry(A1<:U.AccessPasswords
&
A2<:U.AccessPasswords ->
(A1.SecLevel = A2.SecLevel -> A1 = A2))
&
A"A:AccessPasswordEntry(A<:U.AccessPasswords ->
(Dominates(U.MaxSecLevel,A.SecLevel)
&
Dominates(A.SecLevel,U.MinSecLevel)))
```

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-6062/101/00

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))
```

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-6062/101/00

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.ContainingVolume)
&
M.Cylinders.1 <=#Cylinders(M.ContainingVolume)
&
LegalAccessControlList(M)))
```

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-6062/101/00

LegalContainingVolume(M:MiniDiskEntry) =
E"S:SharedVolumeEntry(S<:SharedVolumes &
(S.Volume = M.ContainingVolume;
&
Dominates(S.SecLevel,M.SecLevel)))

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-6062/101/00

LegalAccessControlList(M:MiniDiskEntry) =

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

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-6062/101/00

LegalSharedVolumes =

```
A"S1,S2:SharedVolumeEntry(S1<:SharedVolumes
    &
    S2<:SharedVolumes ->
    (S1.Volume = S2.Volume -> S1 = S2))
&
A"S:SharedVolumeEntry(S<:SharedVolumes ->
    (LegalMap(S)))
```

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-6062/101/00

LegalMap(S:SharedVolumeEntry) =

```
/* non-overlap */
A"M1,M2:CylMap(M1<:S.Map
    &
    M2<:S.Map ->
    (M1.Cylinders.1 > M2.Cylinders.2
    |
    M1.Cylinders.2 < M2.Cylinders.1))
&
A"M:CylMap(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:CylMap(M1<:S.Maps &
    M1.Cylinders.1 = M.Cylinders.2 + 1)))
&
E"M:CylMap(M<:S.Map &
    (M.Cylinders.1 = 1))
&
/* each MiniDisk actually logged */
A"M:CylMap(M<:S.Map ->
    (M.Category = MiniDisk ->
    E"MD:MiniDiskEntry(MD<:MiniDisks &
    (MD.ContainingVolume = S.Volume
    &
    MD.Cylinders = M.Cylinders))))
```

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-6062/101/00

LegalSharableDrives =

```
A"SD1,SD2:SharableDriveEntry(SD1<:SharableDrives
&
SD2<:SharableDrives ->
(SD1.Raddr = SD2.Raddr -> SD1 = SD2))
```

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3.5.2 Updater Process (Formal)

System Development Corporation
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LegalNonsharableDrives =

```
A"NS1,NS2:NonsharableDriveEntry(NS1<:NonsharableDrives
&
NS2<:NonsharableDrives ->
(NS1.Raddr = NS2.Raddr -> NS1 = NS2))
&
A"NS:NonsharableDriveEntry(NS<:NonsharableDrives ->
Ominates(NS.MaxSecLevel,NS.MinSecLevel))
```

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3.5.2 Updater Process (Formal)

System Development Corporation
TM-6062/101/00

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