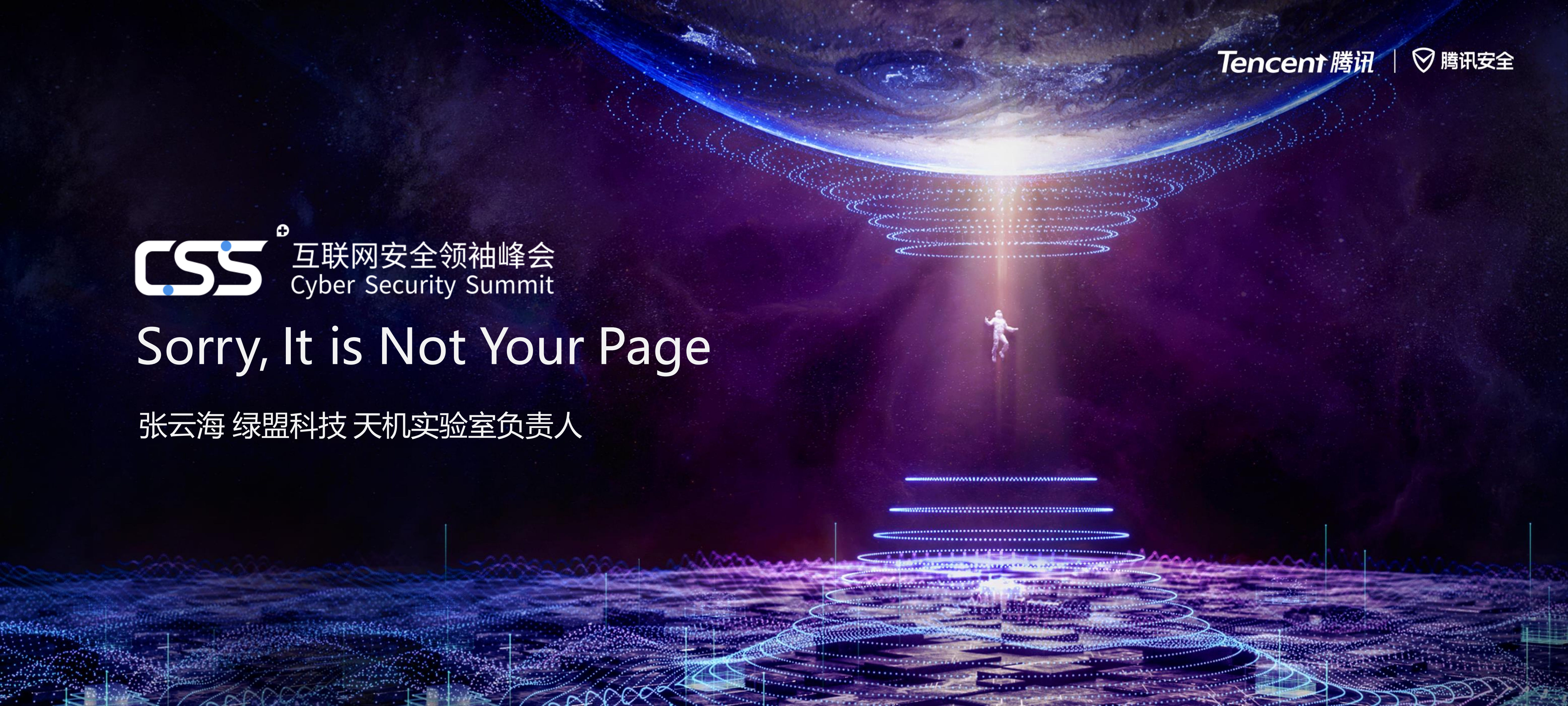
Tencent腾讯 | 腾讯安全

CSS 互联网安全领袖峰会
Cyber Security Summit

Sorry, It is Not Your Page

张云海 绿盟科技 天机实验室负责人



Sorry, It is Not Your Page

演讲者 张云海

Windows 内存管理

Windows 采用分页式内存管理

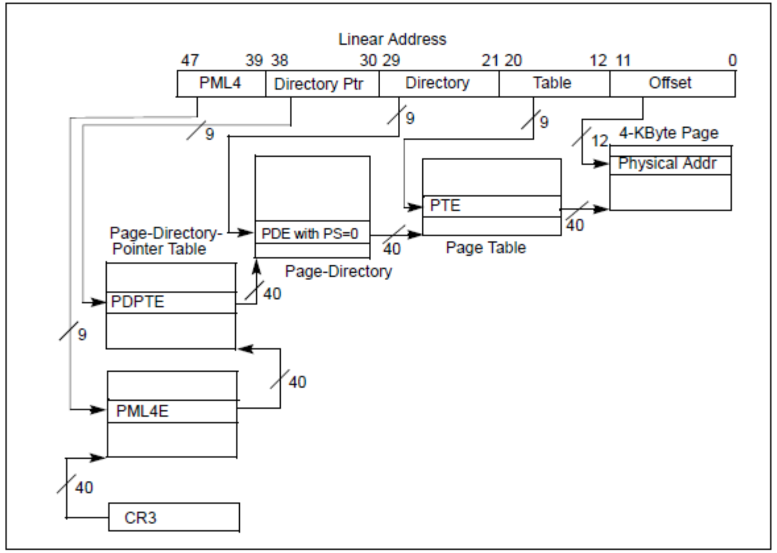
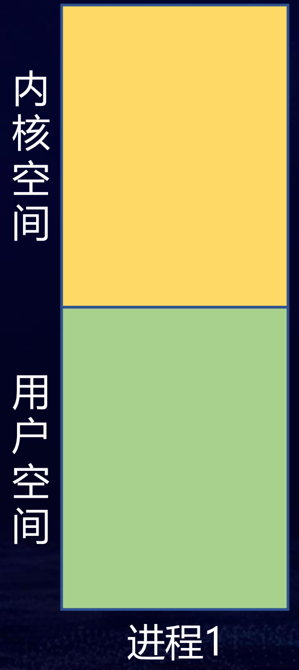
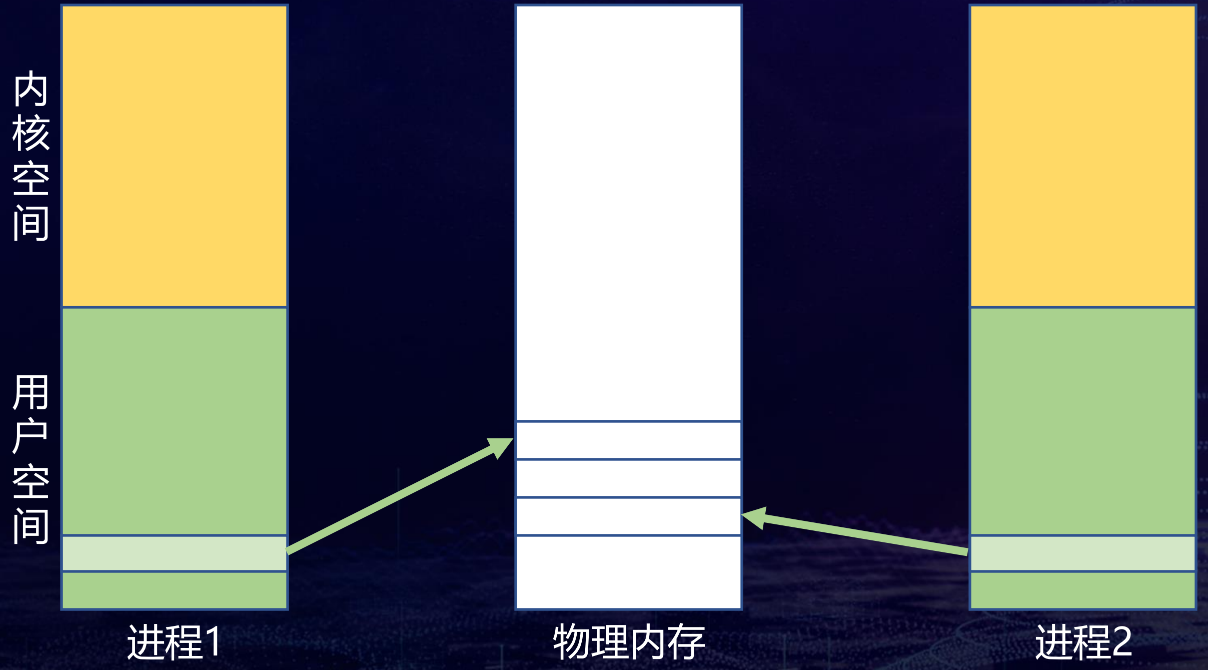


Figure 4-8. Linear-Address Translation to a 4-KByte Page using IA-32e Paging

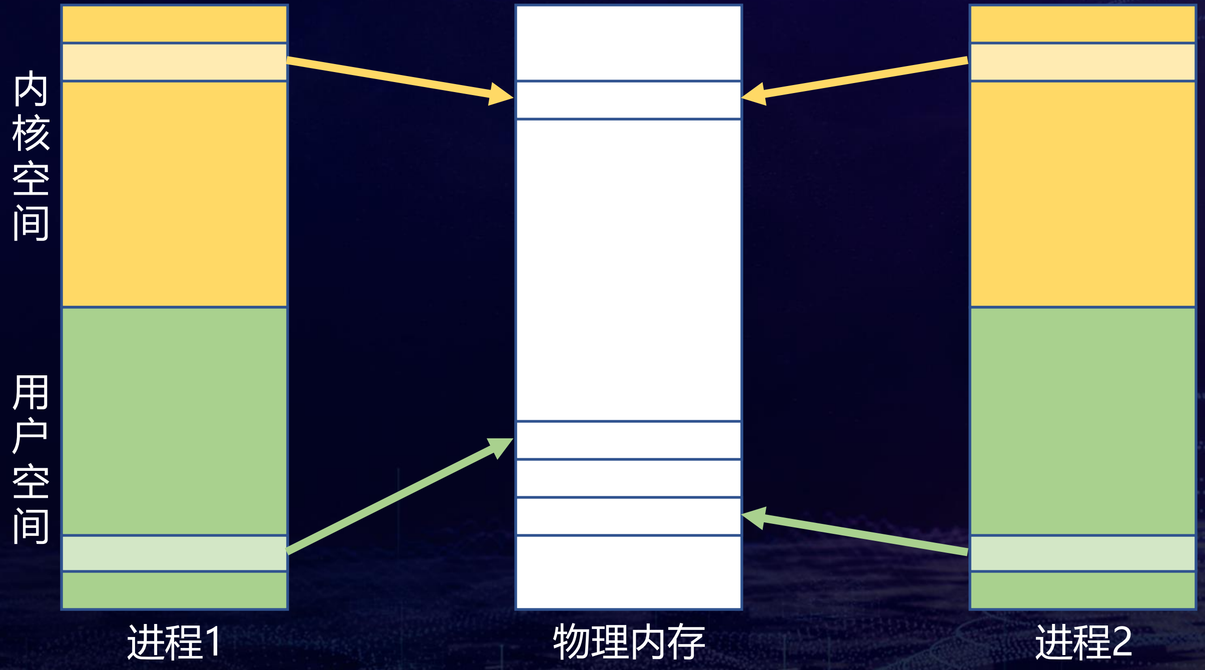
进程的虚拟地址空间分为用户空间和内核空间



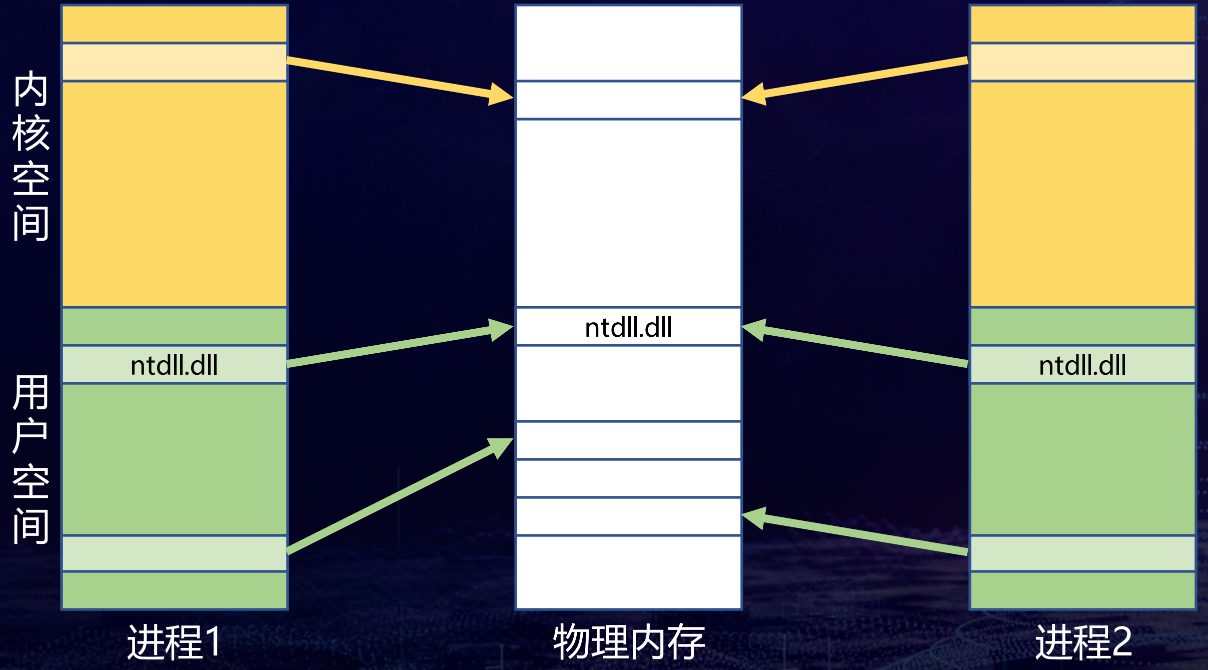
每个进程独占其用户空间



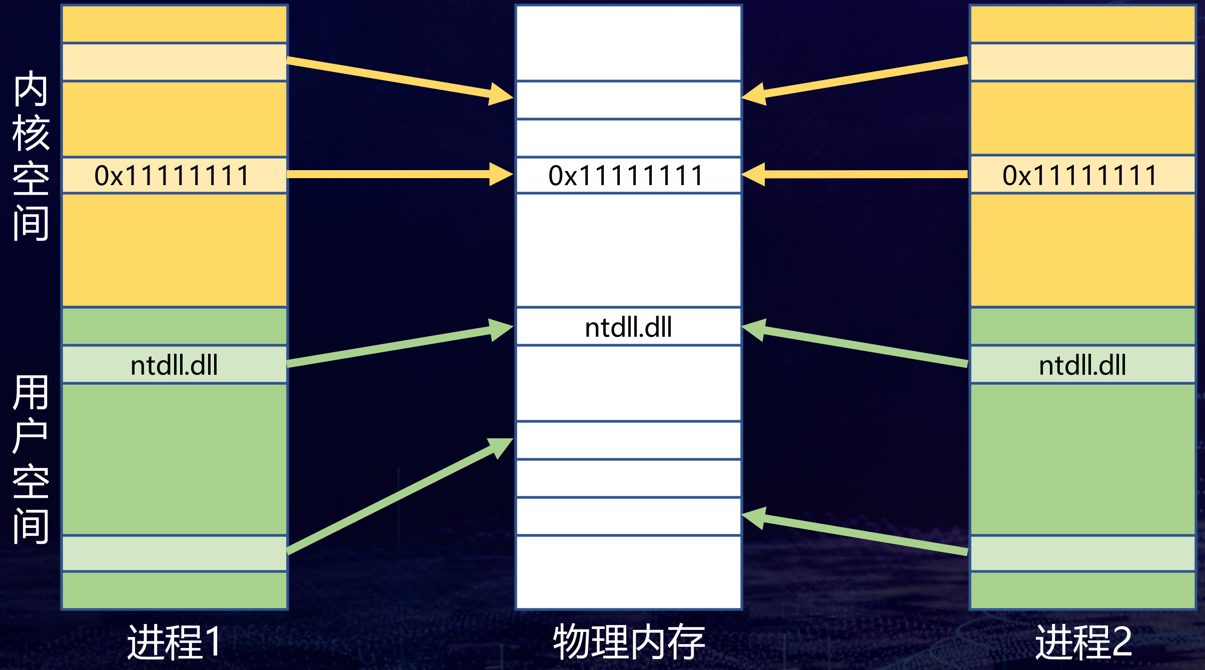
所有进程共享内核空间



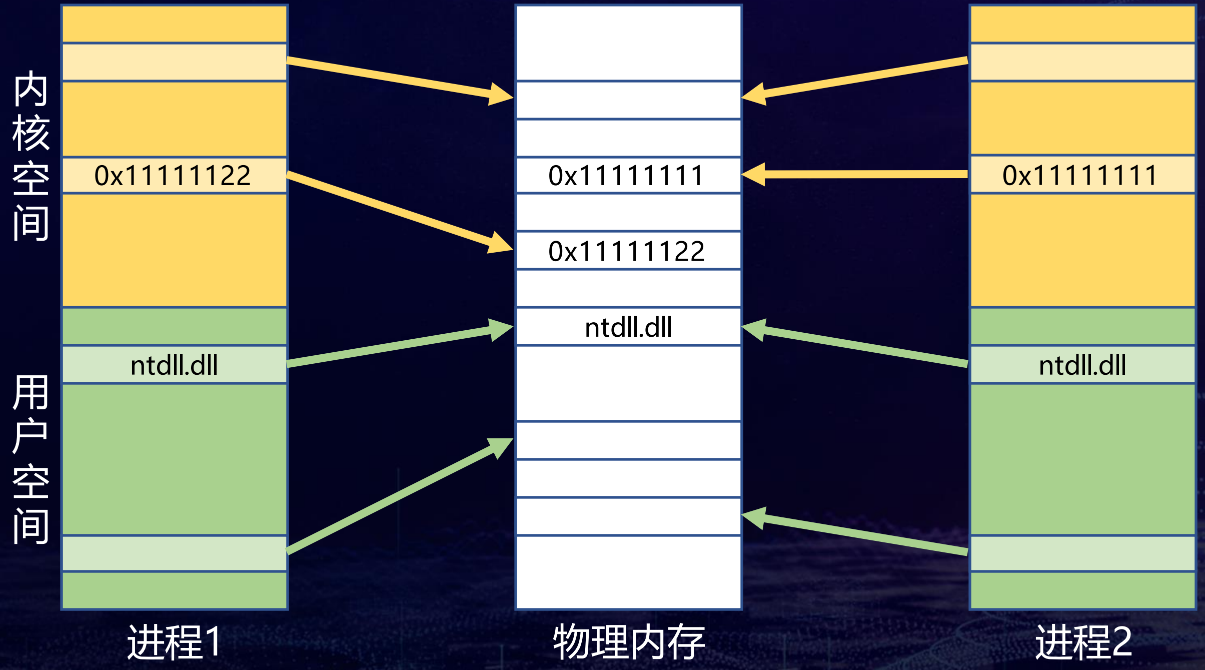
用户空间的内存共享



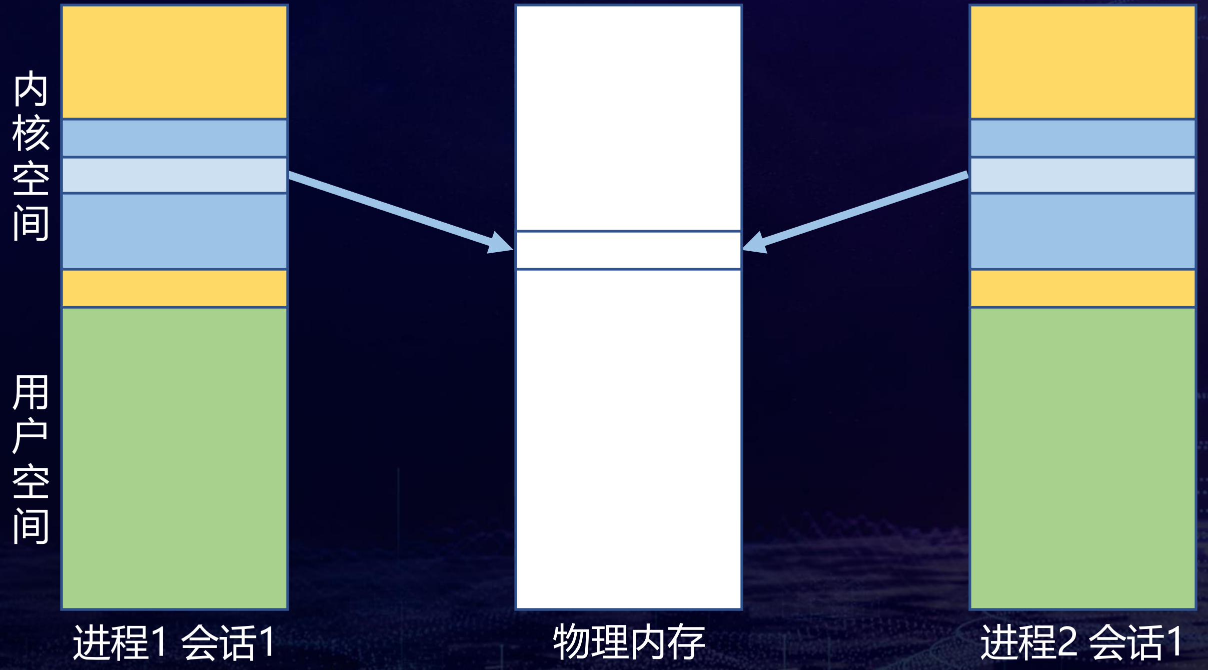
内核空间的写入时复制（Copy-on-Write）



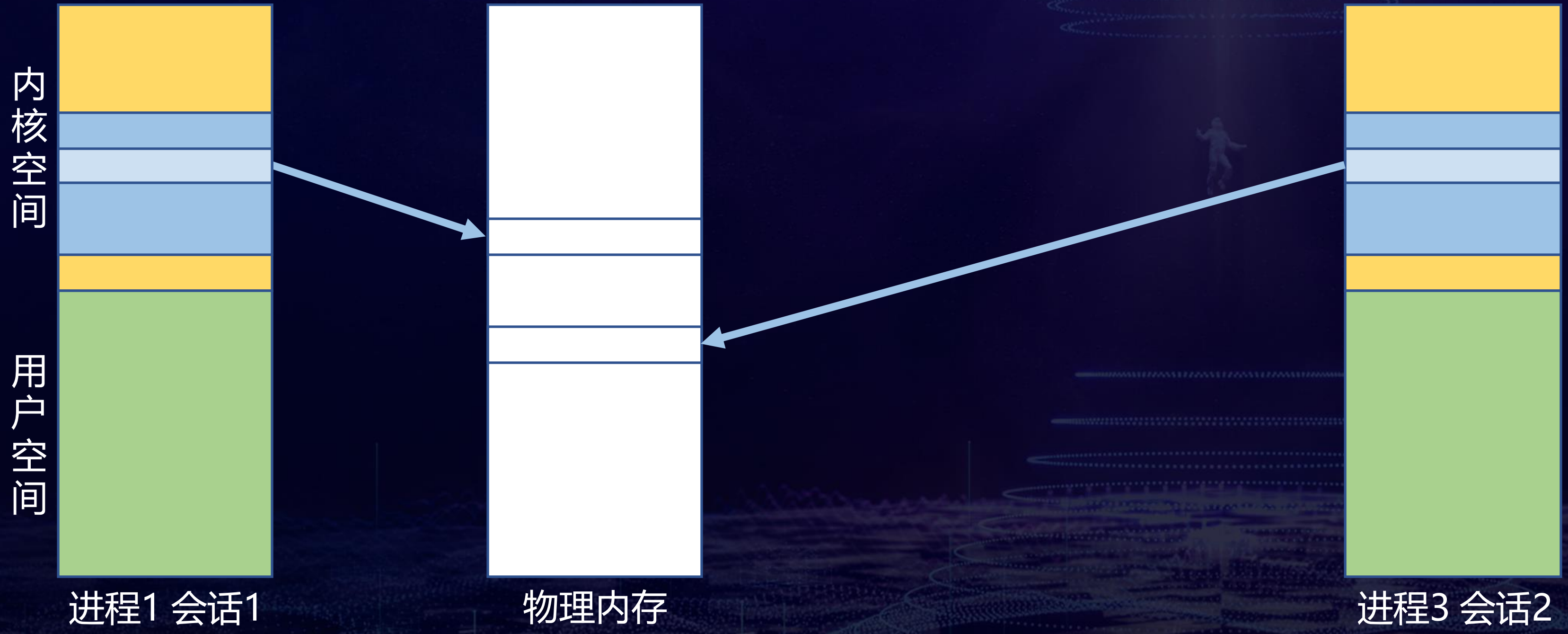
内核空间的写入时复制（Copy-on-Write）



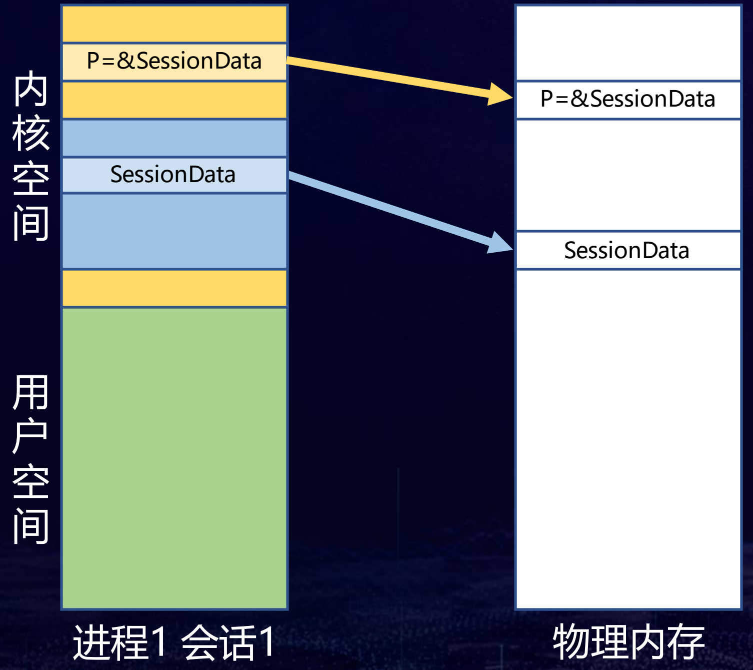
会话空间



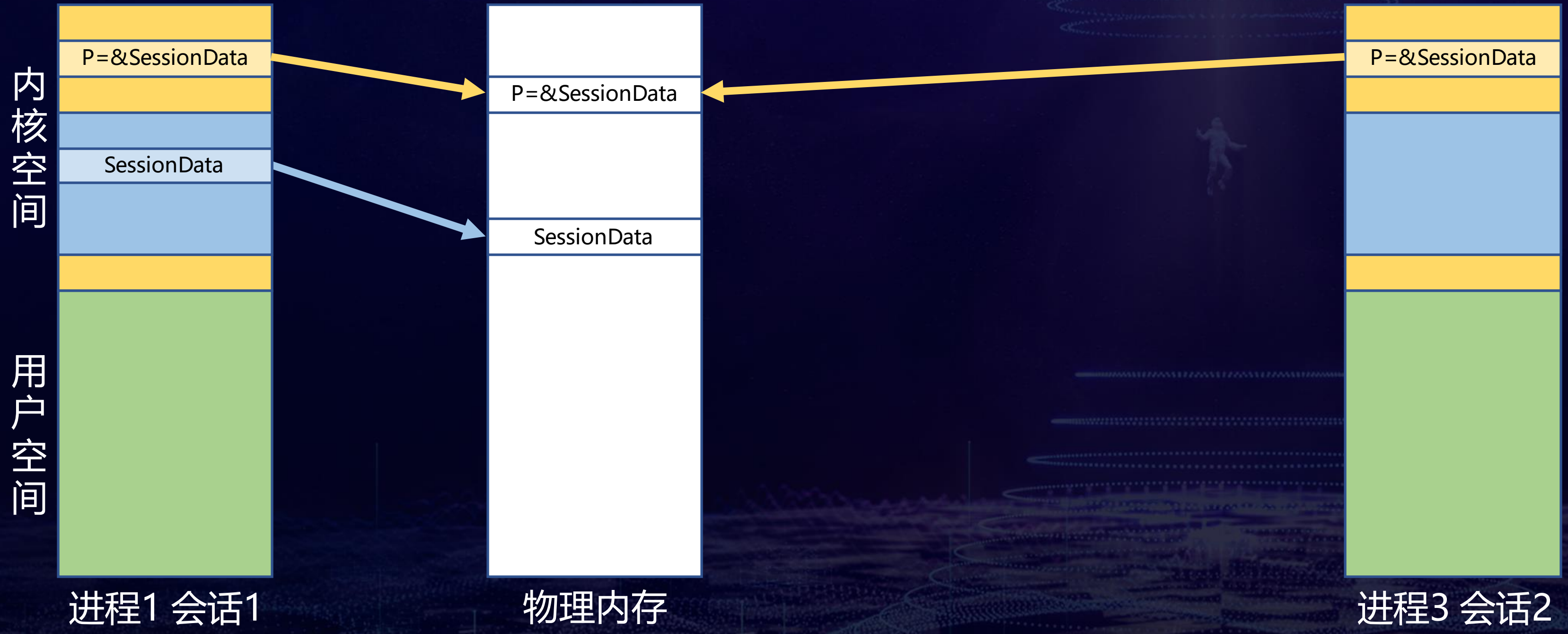
会话空间



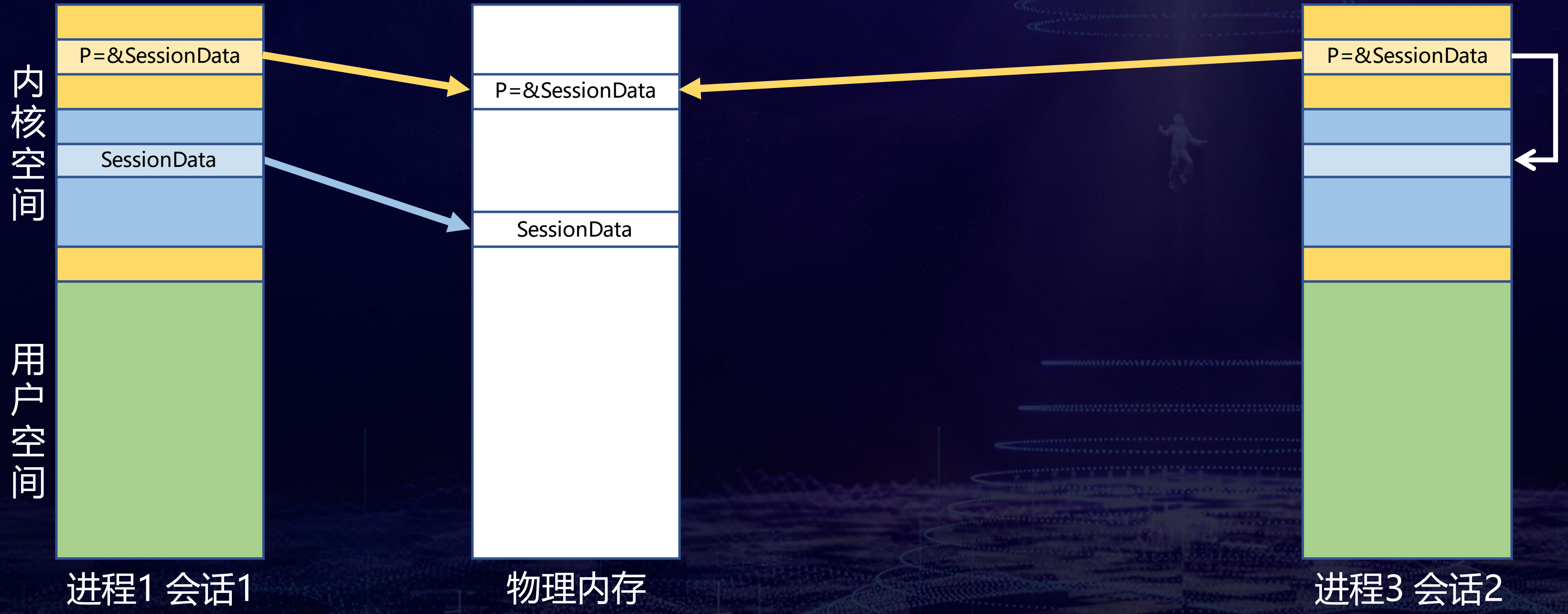
指向会话空间的指针


内核空间
用户空间
P=&SessionData
SessionData
进程1 会话1
P=&SessionData
SessionData
物理内存

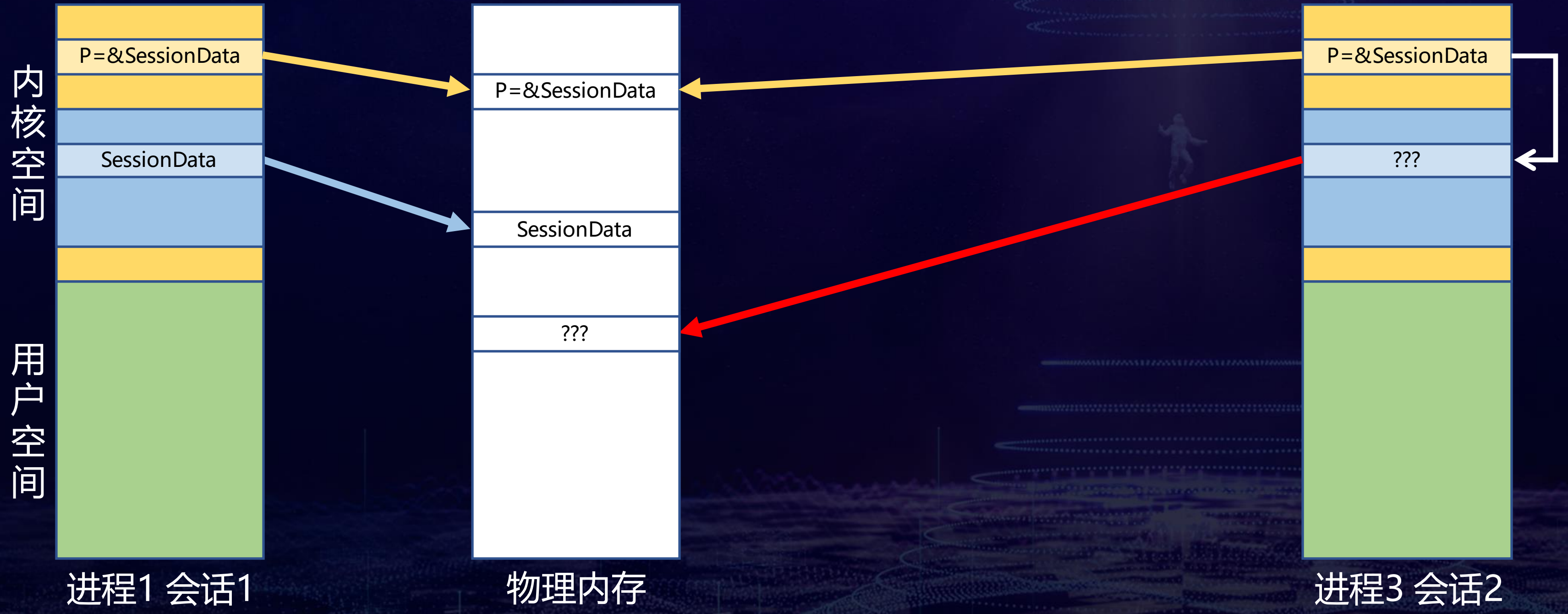
指向会话空间的指针


内核空间
P=&SessionData
SessionData
用户空间
进程1 会话1
P=&SessionData
SessionData
物理内存
P=&SessionData
进程3 会话2

指向会话空间的指针


内核空间
用户空间
P=&SessionData
SessionData
进程1 会话1
P=&SessionData
SessionData
物理内存
P=&SessionData
进程3 会话2

指向会话空间的指针


内核空间
用户空间
P=&SessionData
SessionData
进程1 会话1
P=&SessionData
SessionData
???
物理内存
P=&SessionData
???
进程3 会话2

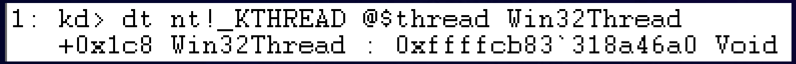
物理页面混淆 Physical Page Confusion

两个问题

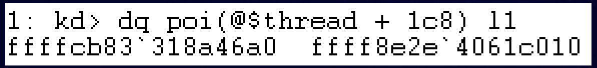
是否存在这样的指针?

如何让其他会话中的进程来使用这个指针?

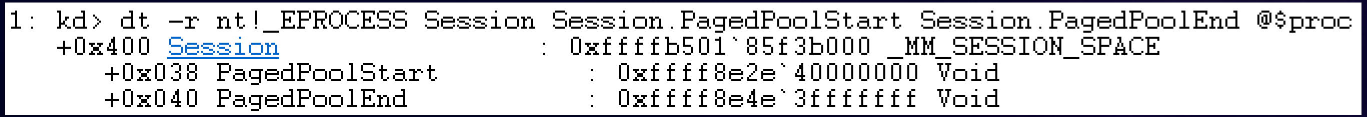
_KTHREAD 中的 Win32Thread



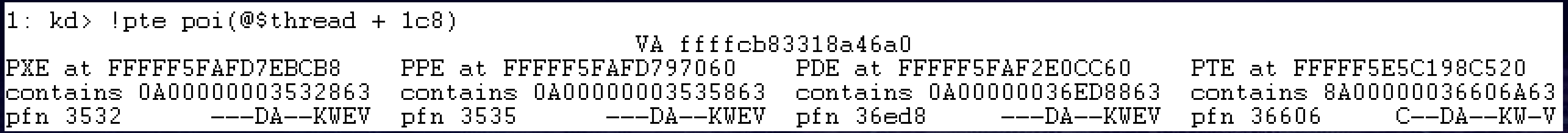
```
1: kd> dt nt!_KTHREAD @$thread Win32Thread
   +0x1c8 Win32Thread : 0xffffcb83`318a46a0 Void
```



```
1: kd> dq poi(@$thread + 1c8) l1
ffffcb83`318a46a0  ffff8e2e`4061c010
```

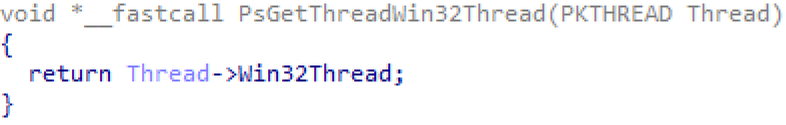


```
1: kd> dt -r nt!_EPROCESS Session Session.PagedPoolStart Session.PagedPoolEnd @$proc
   +0x400 Session                      : 0xffffb501`85f3b000 _MM_SESSION_SPACE
      +0x038 PagedPoolStart               : 0xffff8e2e`40000000 Void
      +0x040 PagedPoolEnd                 : 0xffff8e4e`3fffffff Void
```

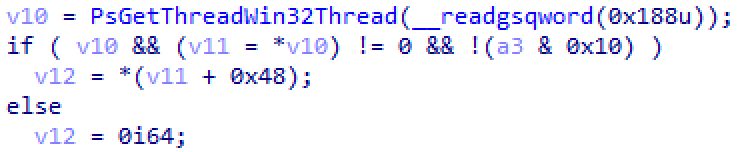


```
1: kd> !pte poi(@$thread + 1c8)
                                           VA ffffcb83318a46a0
PXE at FFFFF5FAFD7EBCB8    PPE at FFFFF5FAFD797060    PDE at FFFFF5FAF2E0CC60    PTE at FFFFF5E5C198C520
contains 0A00000003532863  contains 0A00000003535863  contains 0A000000036ED8863  contains 8A00000036606A63
pfn 3532      ---DA--KWEV  pfn 3535      ---DA--KWEV  pfn 36ed8     ---DA--KWEV  pfn 36606     C--DA--KW-V
```

如何使用 Win32Thread

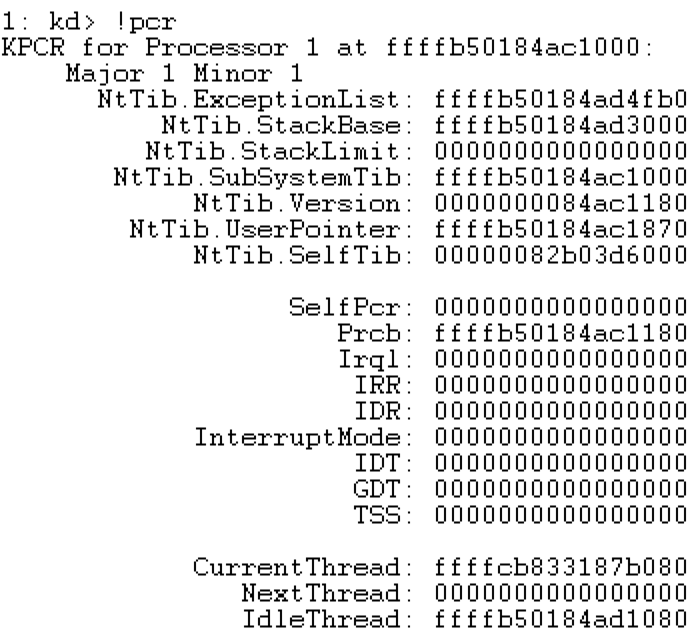


```
void *__fastcall PsGetThreadWin32Thread(PKTHREAD Thread)
{
  return Thread->Win32Thread;
}
```

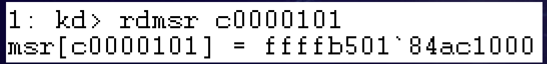


```
v10 = PsGetThreadWin32Thread(__readgsqword(0x188u));
if ( v10 && (v11 = *v10) != 0 && !(a3 & 0x10) )
  v12 = *(v11 + 0x48);
else
  v12 = 0i64;
```

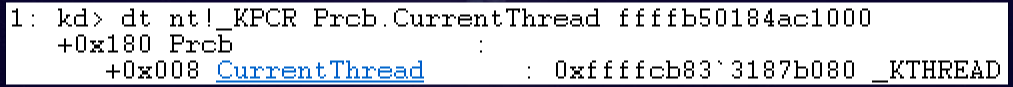
通过 GS 段映射的 _KPCR 获取当前线程



```
1: kd> !pcr
KPCR for Processor 1 at ffffb50184ac1000:
    Major 1 Minor 1
      NtTib.ExceptionList: ffffb50184ad4fb0
          NtTib.StackBase: ffffb50184ad3000
         NtTib.StackLimit: 0000000000000000
       NtTib.SubSystemTib: ffffb50184ac1000
            NtTib.Version: 0000000084ac1180
        NtTib.UserPointer: ffffb50184ac1870
            NtTib.SelfTib: 00000082b03d6000

                  SelfPcr: 0000000000000000
                     Prcb: ffffb50184ac1180
                     Irql: 0000000000000000
                      IRR: 0000000000000000
                      IDR: 0000000000000000
            InterruptMode: 0000000000000000
                      IDT: 0000000000000000
                      GDT: 0000000000000000
                      TSS: 0000000000000000

            CurrentThread: ffffcb833187b080
               NextThread: 0000000000000000
               IdleThread: ffffb50184ad1080
```

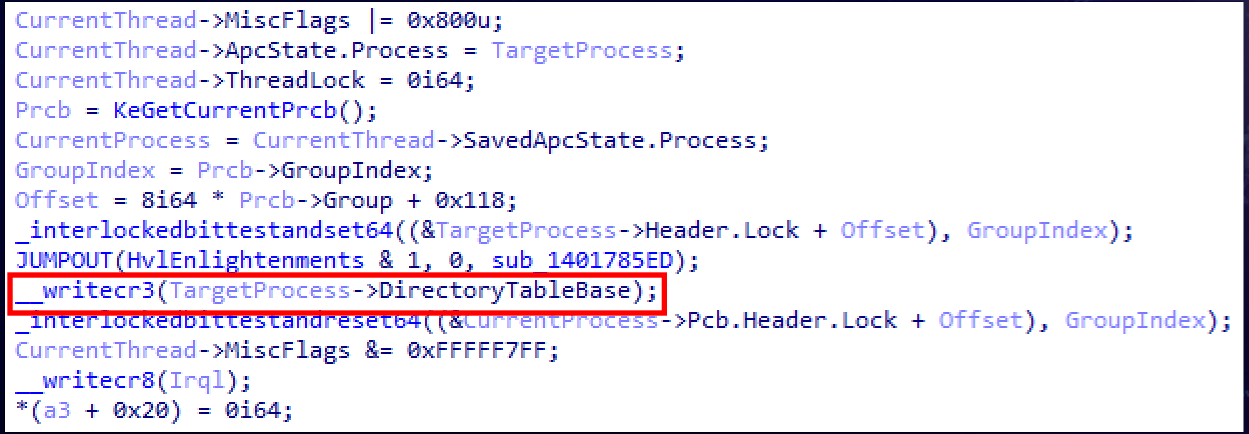


```
1: kd> rdmsr c0000101
msr[c0000101] = ffffb501`84ac1000
```



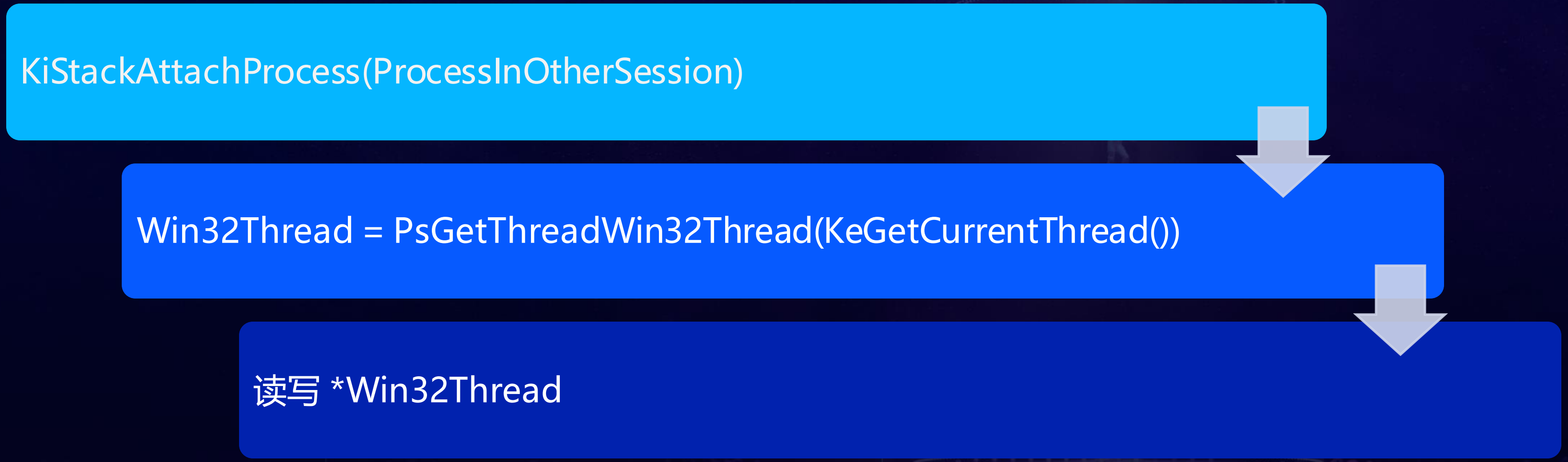
```
1: kd> dt nt!_KPCR Prcb.CurrentThread ffffb50184ac1000
   +0x180 Prcb                  :
      +0x008 CurrentThread         : 0xffffcb83`3187b080 _KTHREAD
```

KiStackAttachProcess 更新 CR3 同时保持 _KPCR.Prcb.CurrentThread 不变



```
CurrentThread->MiscFlags |= 0x800u;
CurrentThread->ApcState.Process = TargetProcess;
CurrentThread->ThreadLock = 0i64;
Prcb = KeGetCurrentPrcb();
CurrentProcess = CurrentThread->SavedApcState.Process;
GroupIndex = Prcb->GroupIndex;
Offset = 8i64 * Prcb->Group + 0x118;
_interlockedbittestandset64((&TargetProcess->Header.Lock + Offset), GroupIndex);
JUMPOUT(HvlEnlightenments & 1, 0, sub_1401785ED);
__writecr3(TargetProcess->DirectoryTableBase);
_interlockedbittestandreset64((&CurrentProcess->Pcb.Header.Lock + Offset), GroupIndex);
CurrentThread->MiscFlags &= 0xFFFFF7FF;
__writecr8(Irql);
*(a3 + 0x20) = 0i64;
```

一个导致物理页面混淆漏洞的模式



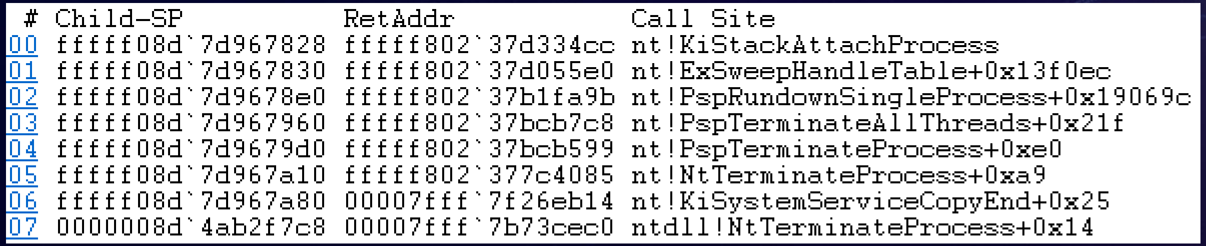
KiStackAttachProcess(ProcessInOtherSession)

Win32Thread = PsGetThreadWin32Thread(KeGetCurrentThread())

读写 *Win32Thread

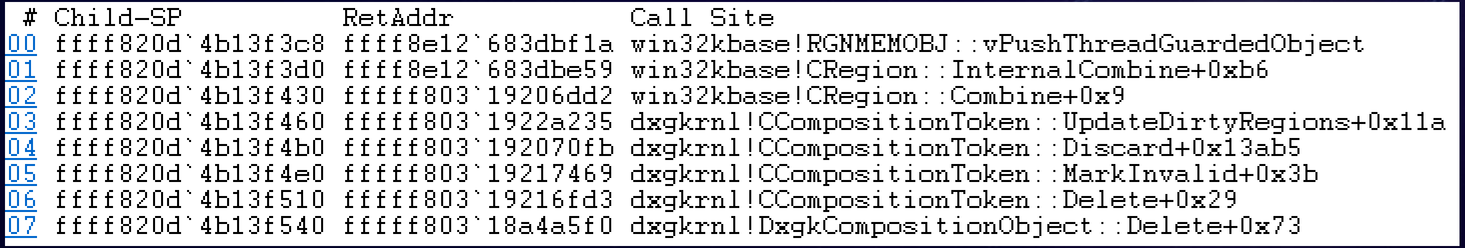
案例分析：CVE-2019-0892

NtTerminateProcess 在关闭句柄前会调用 KiStackAttachProcess



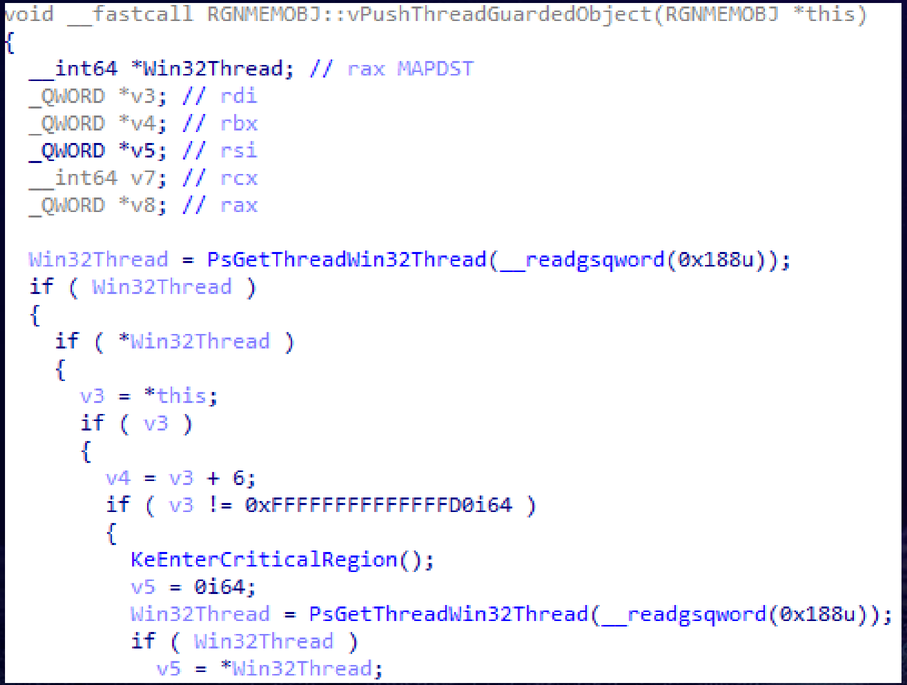
```
 # Child-SP          RetAddr           Call Site
00 fffff08d`7d967828 fffff802`37d334cc nt!KiStackAttachProcess
01 fffff08d`7d967830 fffff802`37d055e0 nt!ExSweepHandleTable+0x13f0ec
02 fffff08d`7d9678e0 fffff802`37b1fa9b nt!PspRundownSingleProcess+0x19069c
03 fffff08d`7d967960 fffff802`37bcb7c8 nt!PspTerminateAllThreads+0x21f
04 fffff08d`7d9679d0 fffff802`37bcb599 nt!PspTerminateProcess+0xe0
05 fffff08d`7d967a10 fffff802`377c4085 nt!NtTerminateProcess+0xa9
06 fffff08d`7d967a80 00007fff`7f26eb14 nt!KiSystemServiceCopyEnd+0x25
07 0000008d`4ab2f7c8 00007fff`7b73cec0 ntdll!NtTerminateProcess+0x14
```

DxgkCompositionObject 对象在删除时会调用 RGNMEMOBJ::vPushThreadGuardedObject

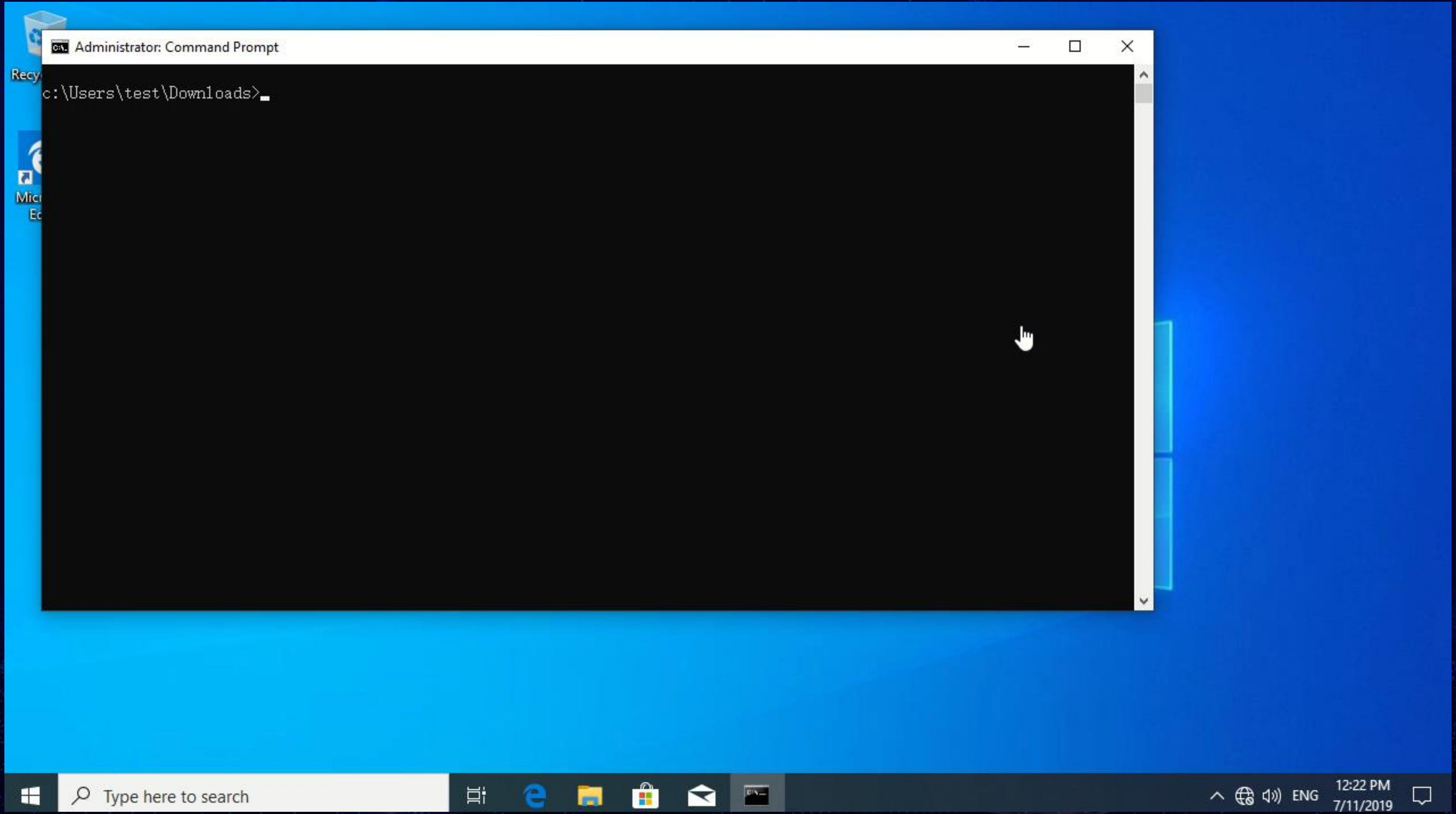


```
 # Child-SP          RetAddr           Call Site
00 ffff820d`4b13f3c8 ffff8e12`683dbf1a win32kbase!RGNMEMOBJ::vPushThreadGuardedObject
01 ffff820d`4b13f3d0 ffff8e12`683dbe59 win32kbase!CRegion::InternalCombine+0xb6
02 ffff820d`4b13f430 ffff803`19206dd2 win32kbase!CRegion::Combine+0x9
03 ffff820d`4b13f460 ffff803`1922a235 dxgkrnl!CCompositionToken::UpdateDirtyRegions+0x11a
04 ffff820d`4b13f4b0 ffff803`192070fb dxgkrnl!CCompositionToken::Discard+0x13ab5
05 ffff820d`4b13f4e0 ffff803`19217469 dxgkrnl!CCompositionToken::MarkInvalid+0x3b
06 ffff820d`4b13f510 ffff803`19216fd3 dxgkrnl!CCompositionToken::Delete+0x29
07 ffff820d`4b13f540 ffff803`18a4a5f0 dxgkrnl!DxgkCompositionObject::Delete+0x73
```

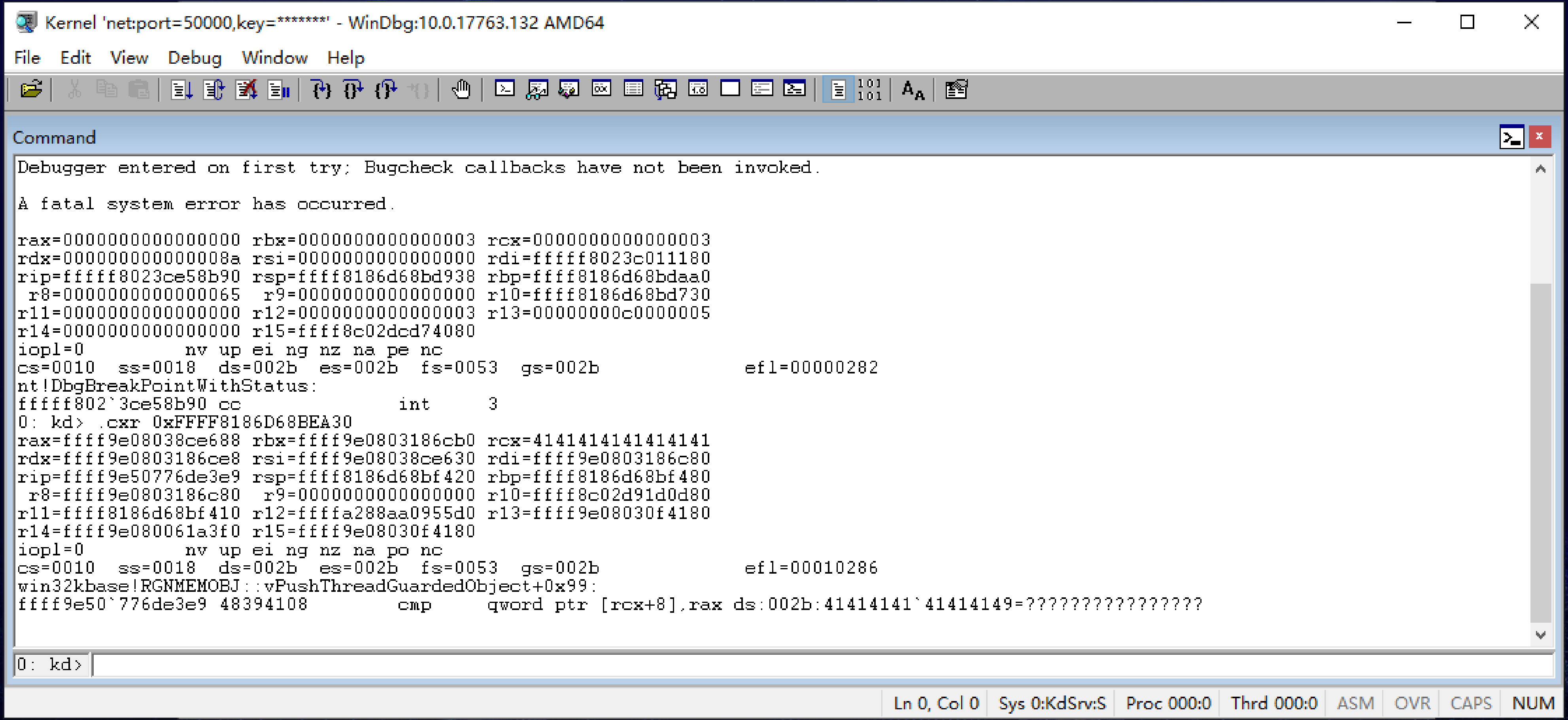
RGNMEMOBJ::vPushThreadGuardedObject 会调用 PsGetThreadWin32Thread 并使用获取的 Win32Thread



```
void __fastcall RGNMEMOBJ::vPushThreadGuardedObject(RGNMEMOBJ *this)
{
  __int64 *Win32Thread; // rax MAPDST
  _QWORD *v3; // rdi
  _QWORD *v4; // rbx
  _QWORD *v5; // rsi
  __int64 v7; // rcx
  _QWORD *v8; // rax

  Win32Thread = PsGetThreadWin32Thread(__readgsqword(0x188u));
  if ( Win32Thread )
  {
    if ( *Win32Thread )
    {
      v3 = *this;
      if ( v3 )
      {
        v4 = v3 + 6;
        if ( v3 != 0xFFFFFFFFFFFFFFD0i64 )
        {
          KeEnterCriticalRegion();
          v5 = 0i64;
          Win32Thread = PsGetThreadWin32Thread(__readgsqword(0x188u));
          if ( Win32Thread )
            v5 = *Win32Thread;
```



```
c:\Users\test\Downloads>_
```



Kernel 'net:port=50000,key=*******' - WinDbg:10.0.17763.132 AMD64
File Edit View Debug Window Help
Command

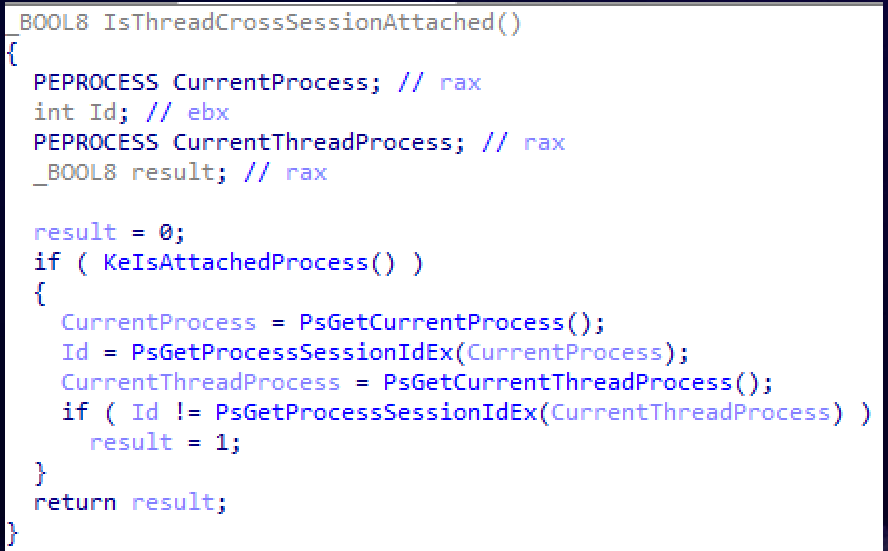
```
Debugger entered on first try; Bugcheck callbacks have not been invoked.

A fatal system error has occurred.

rax=0000000000000000 rbx=0000000000000003 rcx=0000000000000003
rdx=000000000000008a rsi=0000000000000000 rdi=fffff8023c011180
rip=fffff8023ce58b90 rsp=ffff8186d68bd938 rbp=ffff8186d68bdaa0
 r8=0000000000000065  r9=0000000000000000 r10=ffff8186d68bd730
r11=0000000000000000 r12=0000000000000003 r13=00000000c0000005
r14=0000000000000000 r15=ffff8c02dcd74080
iopl=0         nv up ei ng nz na pe nc
cs=0010  ss=0018  ds=002b  es=002b  fs=0053  gs=002b             efl=00000282
nt!DbgBreakPointWithStatus:
fffff802`3ce58b90 cc              int     3
0: kd> .cxr 0xFFFF8186D68BEA30
rax=ffff9e08038ce688 rbx=ffff9e0803186cb0 rcx=4141414141414141
rdx=ffff9e0803186ce8 rsi=ffff9e08038ce630 rdi=ffff9e0803186c80
rip=ffff9e50776de3e9 rsp=ffff8186d68bf420 rbp=ffff8186d68bf480
 r8=ffff9e0803186c80  r9=0000000000000000 r10=ffff8c02d91d0d80
r11=ffff8186d68bf410 r12=ffffa288aa0955d0 r13=ffff9e08030f4180
r14=ffff9e080061a3f0 r15=ffff9e08030f4180
iopl=0         nv up ei ng nz na po nc
cs=0010  ss=0018  ds=002b  es=002b  fs=0053  gs=002b             efl=00010286
win32kbase!RGNMEMOBJ::vPushThreadGuardedObject+0x99:
ffff9e50`776de3e9 48394108        cmp     qword ptr [rcx+8],rax ds:002b:41414141`41414149=????????????????
```

```
0: kd>
```

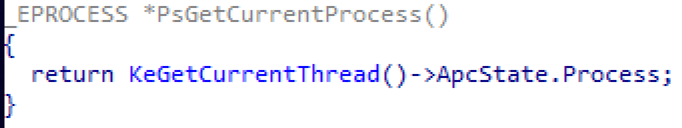
Ln 0, Col 0 | Sys 0:KdSrv:S | Proc 000:0 | Thrd 000:0 | ASM | OVR | CAPS | NUM

问题修复

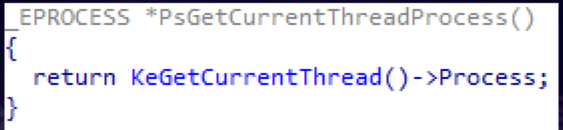
引入函数 IsThreadCrossSessionAttached 进行检查



```
_BOOL8 IsThreadCrossSessionAttached()
{
  PEPROCESS CurrentProcess; // rax
  int Id; // ebx
  PEPROCESS CurrentThreadProcess; // rax
  _BOOL8 result; // rax

  result = 0;
  if ( KeIsAttachedProcess() )
  {
    CurrentProcess = PsGetCurrentProcess();
    Id = PsGetProcessSessionIdEx(CurrentProcess);
    CurrentThreadProcess = PsGetCurrentThreadProcess();
    if ( Id != PsGetProcessSessionIdEx(CurrentThreadProcess) )
      result = 1;
  }
  return result;
}
```

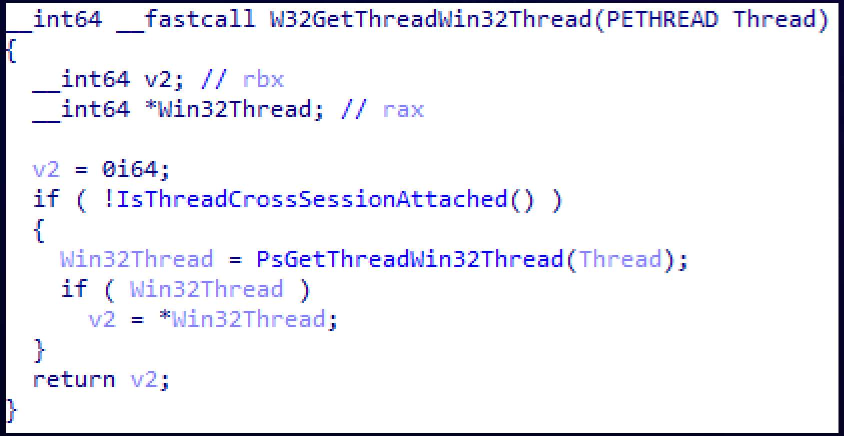


```
_EPROCESS *PsGetCurrentProcess()
{
  return KeGetCurrentThread()->ApcState.Process;
}
```



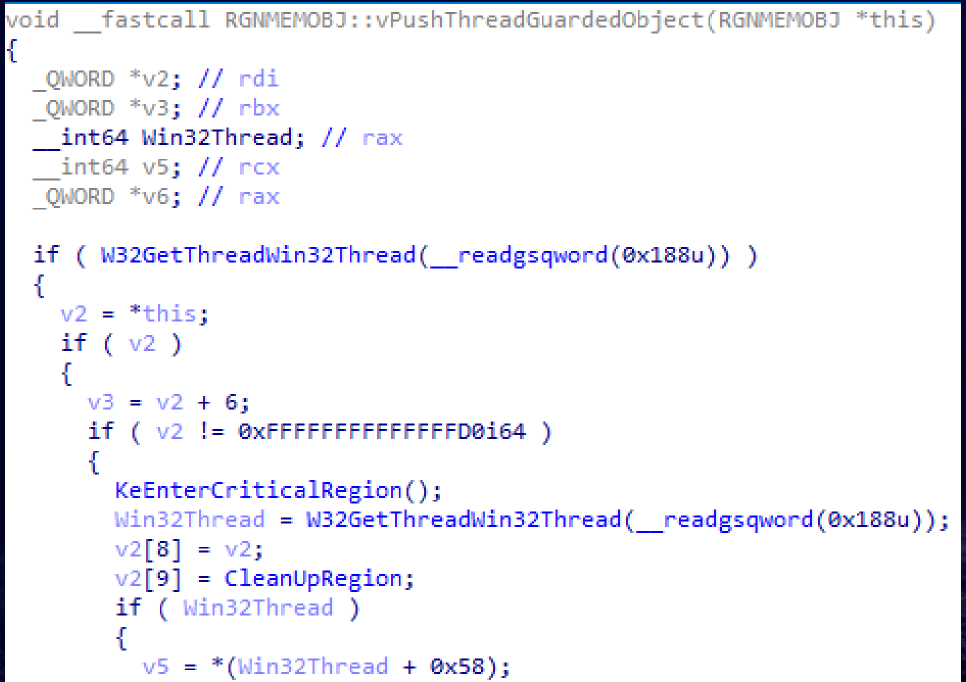
```
_EPROCESS *PsGetCurrentThreadProcess()
{
  return KeGetCurrentThread()->Process;
}
```

用 W32GetThreadWin32Thread 封装 PsGetThreadWin32Thread



```
__int64 __fastcall W32GetThreadWin32Thread(PETHREAD Thread)
{
  __int64 v2; // rbx
  __int64 *Win32Thread; // rax

  v2 = 0i64;
  if ( !IsThreadCrossSessionAttached() )
  {
    Win32Thread = PsGetThreadWin32Thread(Thread);
    if ( Win32Thread )
      v2 = *Win32Thread;
  }
  return v2;
}
```

RGNMEMOBJ::vPushThreadGuardedObject 调用 W32GetThreadWin32Thread 获取 Win32Thread



```
void __fastcall RGNMEMOBJ::vPushThreadGuardedObject(RGNMEMOBJ *this)
{
  _QWORD *v2; // rdi
  _QWORD *v3; // rbx
  __int64 Win32Thread; // rax
  __int64 v5; // rcx
  _QWORD *v6; // rax

  if ( W32GetThreadWin32Thread(__readgsqword(0x188u)) )
  {
    v2 = *this;
    if ( v2 )
    {
      v3 = v2 + 6;
      if ( v2 != 0xFFFFFFFFFFFFFFD0i64 )
      {
        KeEnterCriticalRegion();
        Win32Thread = W32GetThreadWin32Thread(__readgsqword(0x188u));
        v2[8] = v2;
        v2[9] = CleanUpRegion;
        if ( Win32Thread )
        {
          v5 = *(Win32Thread + 0x58);
```

增加 IsThreadCrossSessionAttached 检查的函数

NtGdiDeleteObjectApp
bDeleteDCOBJ
GreGetDeviceCaps
ReleaseCacheDC
_GetDCEx
GreGetBounds
XDCOBJ::bCleanDC
HmgDecrementShareReferenceCountEx
HmgLockEx

HANDLELOCK::vLockHandle
ResetOrg
HANDLELOCK::bLockHobj
hbmSelectBitmap
DCMEMOBJ::DCMEMOBJ
W32GetThreadWin32Thread
SURFMEM::bCreateDIB
XDCOBJ::bDeleteDC
GreIntersectClipRect

Call to Action

使用错误的页表进行虚拟地址转换会导致物理页面混淆类漏洞

操作系统应当提供机制来判断是否可以安全的使用虚拟地址

开发人员应当认识到这类漏洞的存从而做出相应的处理

感 谢 聆 听